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CERC WAVE GAGES

by

Leo C. Williams

TECHNICAL MEMORANDUM NO. 30

DECEMBER 1969

U. S. ARMY, CORPS OF ENGINEERS

COASTAL ENGINEERING RESEARCH CENTER

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ABSTRACT

CERC has used wave gages to gather prototype wave data since 1948. Two basic types of gages are now used in the field - the step-resistance staff gage and the underwater pressure-sensitive gage. CERC has developed three types of step-resistance staff gages - a series type for use in fresh water, a parallel type for use in salt water, and a relay-operated type for use in either fresh or salt water or in water where wide changes in salinity occur. The pressure gage can be used in water of any salinity. The series and parallel gages have an accuracy of ±5 percent plus the spacing of one sensor increment. The relay gage has an accuracy of ±2 percent plus the spacing of one sensor increment. The accuracy of the pressure-sensitive gage is not as precise as that of the step-resistance gages.

The report describes each gage and the theory of operation, details of fabrication, steps for calibration and installation, and requirements of maintenance.

FOREWORD

This report describes in detail the sensors and recorders used by CERC in wave-data collection programs. Leo C. Williams, Chief of the Instrumentation and Equipment Branch, Research Division, prepared this report and developed most of the wave-data equipment used at CERC. Thorndike Saville, Jr. is Chief of the Research Division. The manuscript was prepared in 1966.

Many drawings in this publication have been greatly reduced from the originals. The large originals are available at CERC in limited quantities.

At the time of publication, Lieutenant Colonel Edward M. Willis was Director of the Center; Joseph M. Caldwell was Technical Director.

NOTE: Comments on this publication are invited. Discussion will be published in the next issue of the CERC Bulletin.

This report is published under authority of Public Law 166, 79th Congress, approved July 31, 1945, as supplemented by Public Law 172, 88th Congress, approved November 7, 1963.

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Section I. INTRODUCTION

1. Wave Program at CERC

The Coastal Engineering Research Center (CERC), formerly the Beach Erosion Board, has been collecting data from wave gages for more than 20 years. The program started in April 1948, when the first gages were installed in New Jersey. Since then, many gages have been installed. In addition to gages on the Atlantic, Gulf of Mexico, and Pacific shores, gages have been installed in the Great Lakes, at Hawaii, and in smaller inland lakes and reservoirs.

Signals from 7 locations and 10 gages are now instantaneously recorded on a central panel in the CERC Laboratory. These signals are carried by leased telephone lines.

CERC uses two basic types of wave gages - the step-resistance staff gage and the pressure-sensitive gage. The more accurate is the step-resistance gage and it is favored for use in locations where a structure is available for its installation or where the construction of a suitable support is feasible. The pressure-sensitive underwater gage is selected for those sites where a less accurate gage is acceptable for a measurement program, and where the measurement of waves with periods of less than 4 seconds is not required.

2. Recording and Analysis

Recordings from both types of gages are normally produced on a pen and ink paper strip-chart recorder. The length of time that the waves are recorded is selected in accordance with the mission of the individual gage or within the overall program of wave study. Automatic programming of the gage recording time is normally provided along with a control for manual selection of special recording periods.

Tide changes are not normally removed from the strip-chart recordings taken with the staff type step-resistance wave gage. However, tide removal can be provided for this gage should the requirement for this type operation arise. Tide changes are removed from the pressure-sensitive wave gage. If such removal was not incorporated in the gage operation, barometric changes would also be present in the recording, thus a record that would be difficult to analyze would be produced.

Data from both types of wave gages may be recorded on magnetic tape. Records made on magnetic tape are analyzed on a spectrum analyzer in the CERC Laboratory. The analyzer performs the following analyses from a 20-minute recording:

a) Linear average wave height.
b) Squared average wave height.
c) Linear peak wave height.

d) Squared peak wave height.
e) Linear integrated wave height.
f) Squared integrated wave height.

These values are presented on the vertical axis of the spectral plot with the corresponding wave period presented on the horizontal axis of the plot.

The magnetic tape recorder usually records wave conditions continuously using a tape speed of 1/2 inch per minute. One roll of 1/4 inch wide magnetic tape 1,250 feet long, records continuously for approximately 3 weeks.

The magnetic tape recorder has a built-in calibration generator (sine wave) with a period of 4 seconds. The calibration signal is adjusted to provide an amplitude equal to that produced by the wave gage for full-scale recording on the strip chart and magnetic tape. This calibration signal is recorded for 30 minutes every 12 hours to provide a standardization signal to compensate for changes found in magnetic tape from roll to roll, and to calibrate the entire spectrum analyzer in the laboratory. The calibration signal is timed by a program clock connected with the tape recorder.

3. Types of Wave Gages

The staff type step-resistance wave gage is available for three different applications:

a) Series step-resistance type for use in fresh water.

b) Parallel step-resistance type for use in salt water locations where little or no change occurs in salinity.

c) Relay-operated step-resistance type that will operate in either fresh water or salt water and where wide changes in salinity occur.

The accuracy of the recording taken with the fresh-water, series, step-resistance gage and the salt-water, parallel, step-resistance gage is about plus or minus 5 percent, plus the spacing of one staff-sensing point.

The accuracy of the recording taken with the relay-operated step-resistance gage is about plus or minus 2 percent plus the spacing of one staff sensing point. Due to the increased accuracy expected of this gage, servicing and cleaning of the sensing elements may have to be performed more often than on the other two step-resistance gages. This service will depend on local conditions of sea growth at the gage site.

The sensing units for the staff type step-resistance wave gages are molded from epoxy resin in 5-foot lengths, and are stacked in a steel or

aluminum holder to provide the gage length desired for the location, usually 15 to 25 feet. Sensing contacts are molded into the 5-foot sections at intervals to provide the incremental accuracy required of the gage. Sensing contacts spaced every 0.2 foot have been found adequate for gages with lengths of 15 to 25 feet. Sensing contacts spaced 0.1 foot have been used on gages of 10 feet or less.

The sensing unit for the pressure-sensitive underwater wave gage senses the change in pressure produced by the increase (or decrease) in water height as the wave passes over the gage. The change in pressure produced by a wave with an 8-second period with a height of 4 feet on a gage submerged in 30 feet of water will be less than that produced by the same wave on the same wave gage submerged in 10 feet of water. A wave with a period shorter than 8 seconds and with a height of 4 feet will produce less pressure at both the 30-foot and 10-foot depths than the 8-second wave. This phenomena is referred to as a pressure gradient condition produced as a function of wave height versus wave period versus water depth to the sensing element.

The pressure-sensing element used by the CERC is designed for use in locations where the total water depth (stillwater depth plus height of wave crest) is less than 50 feet. Sensing elements with similar characteristics that are interchangeable with the CERC model except for the d.c. power requirements are available from commercial sources. One of these is Fairchild Semi-Conductor Corporation Model TF 150 series. These sensors are available in a variety of pressure ranges and may be used in water depths greater than the 50-foot total range of the CERC model. However, use of a pressure-sensitive gage in water depths greater than 30 feet is not advised due to the depth-period attenuation factor of recordings taken from such an installation.

Figure 1 shows a block diagram of the components used in a series-type step-resistance wave gage for use in fresh water.

Figure 2 shows a block diagram of a parallel-type step-resistance wave gage for use in salt water.

Figure 3 shows a block diagram of a relay-operated step-resistance wave gage for use in water of varying salinity.

Figure 4 shows a block diagram of a pressure-sensitive wave gage.

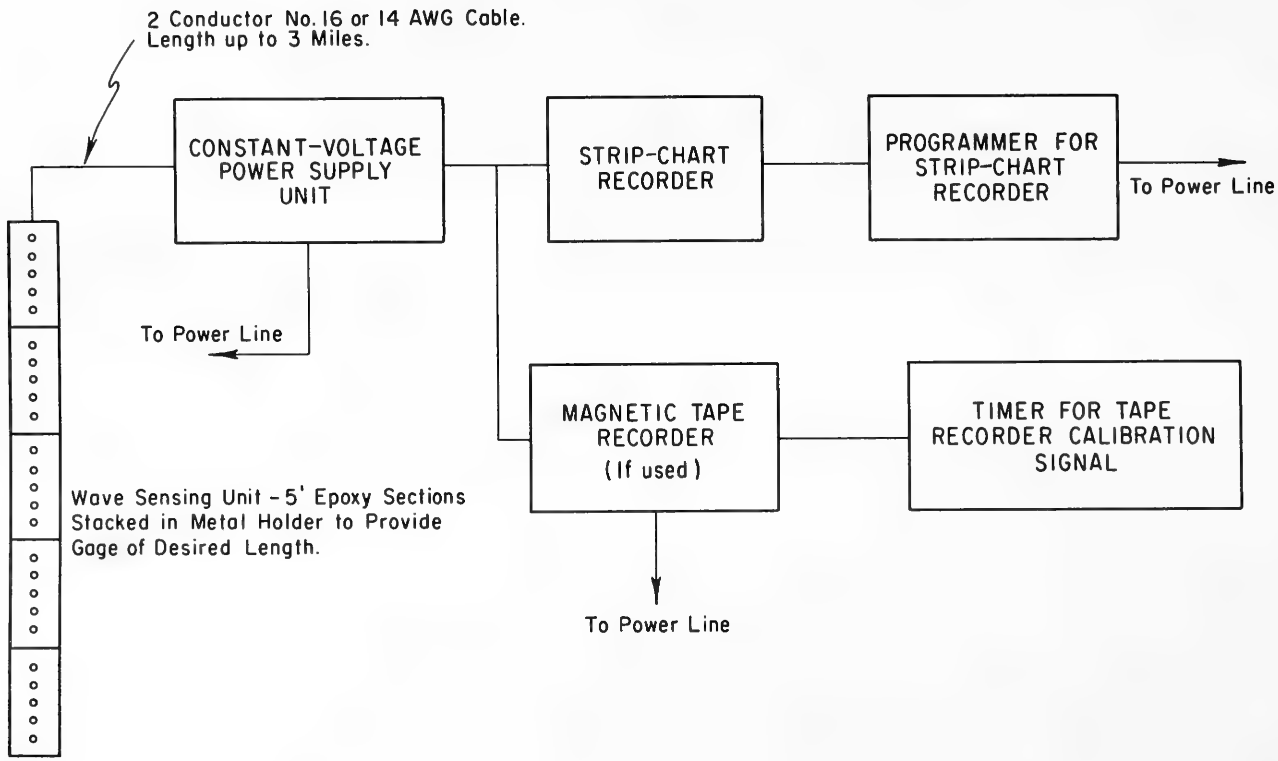

Figure 1. Block Diagram of Series-Type Step-Resistance Gage for Fresh Water.

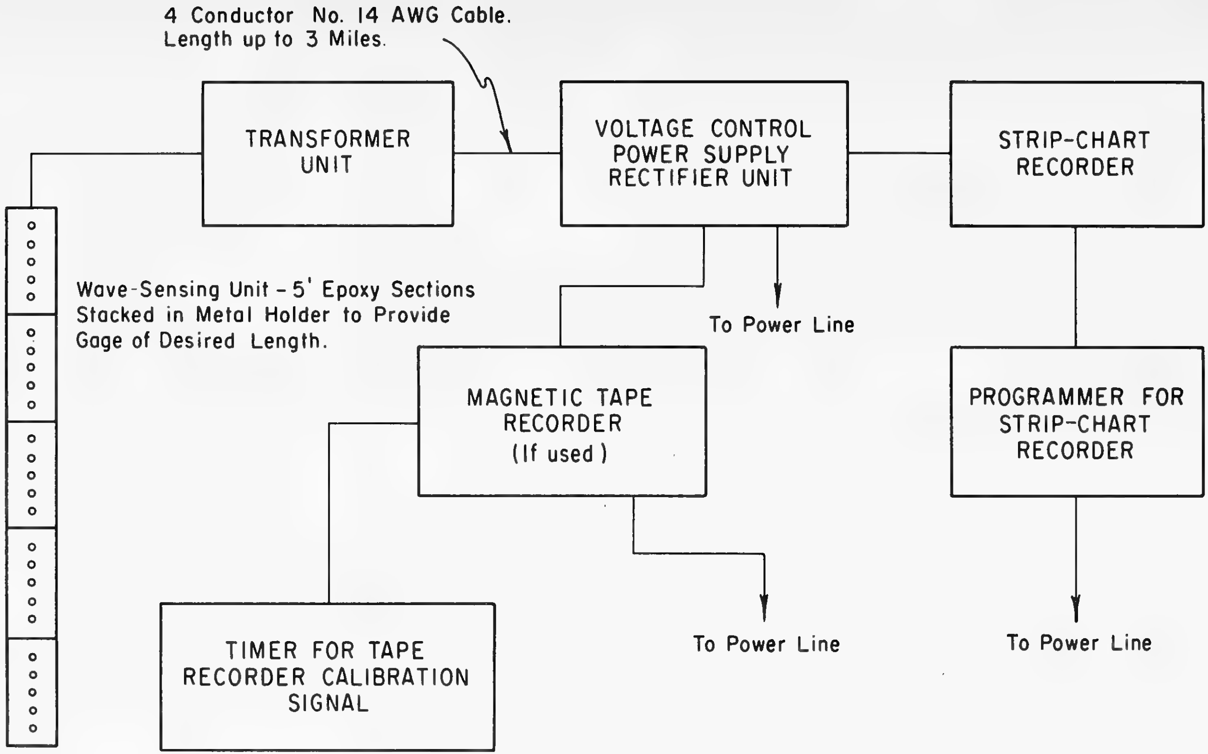

Figure 2. Block Diagram of Parallel Step-Resistance Gage for Salt Water.

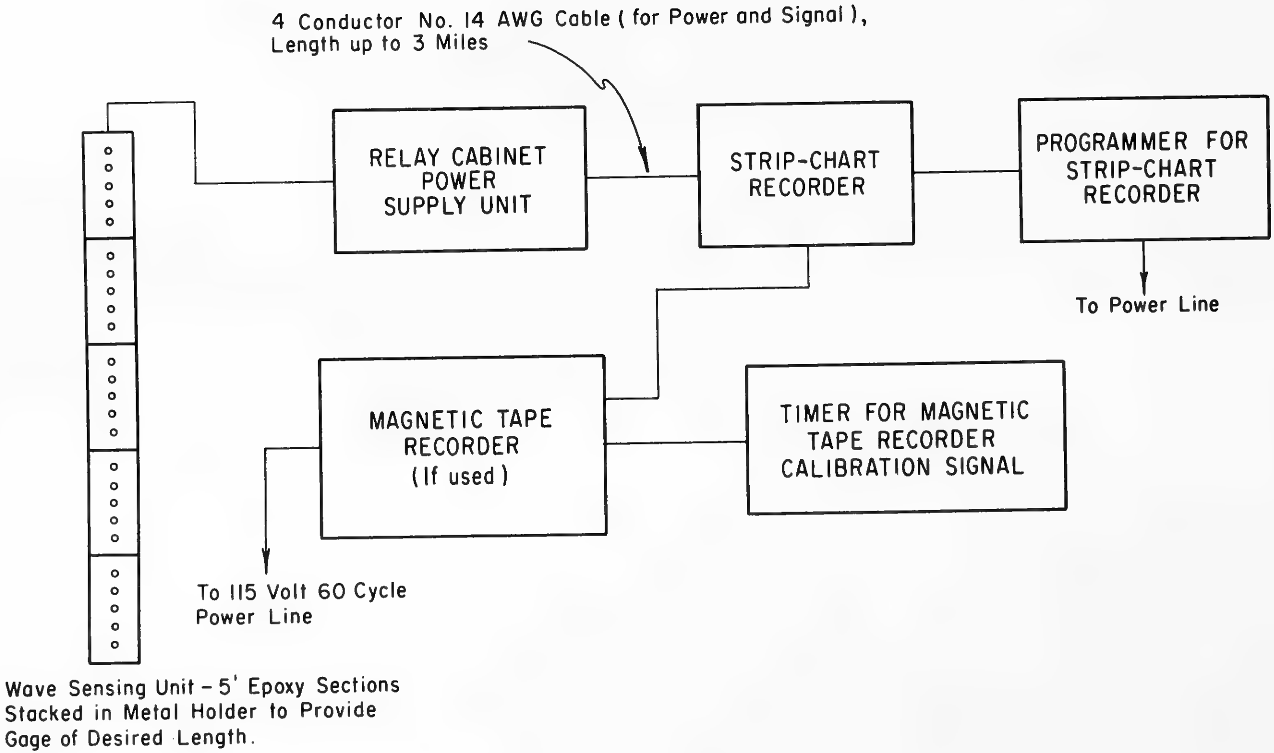

Figure 3. Block Diagram of Relay-Operated Step-Resistance Gage.

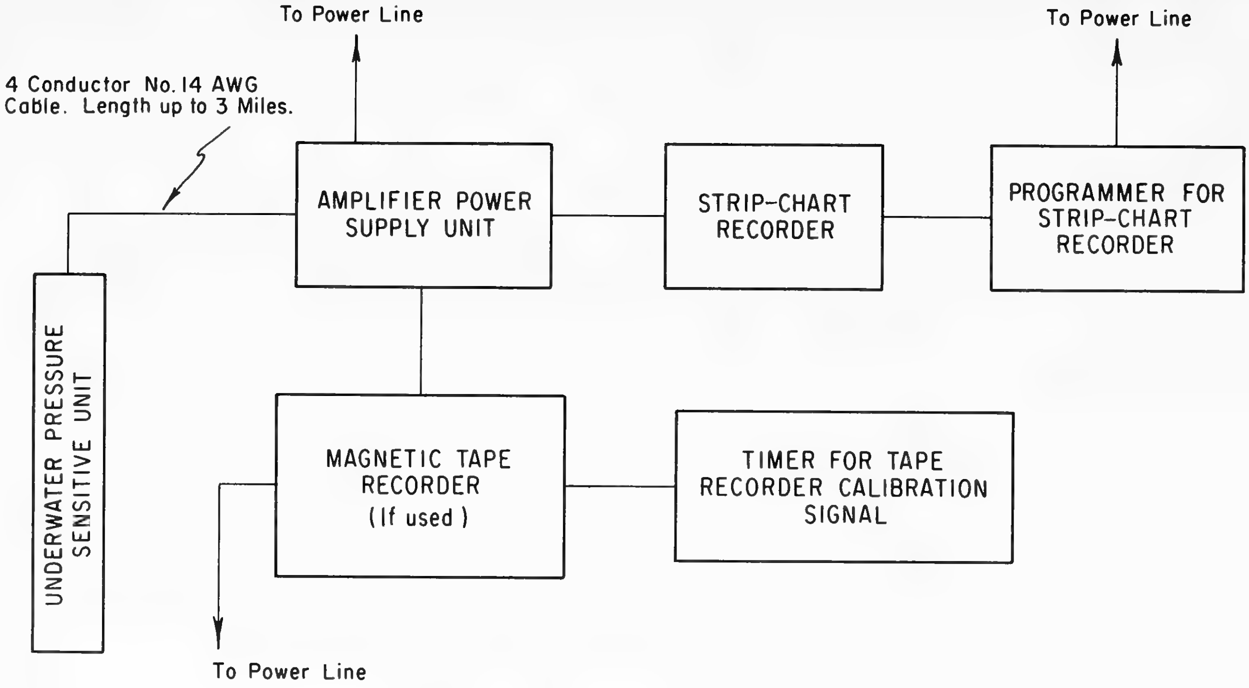

Figure 4. Block Diagram of Pressure-Sensitive Wave Gage.

Section II. SERIES-TYPE, STEP-RESISTANCE GAGE FOR USE IN FRESH WATER

1. Theory of Operation of Series-Type, Step-Resistance Gage

The series-type, step-resistance gage operates on the principle of a simple series-type circuit with a constant voltage d.c. source, a recorder penmotor and a variable resistor connected in series. Figure 5 shows a simple series circuit containing a constant voltage source, the penmotor, and a variable resistance.

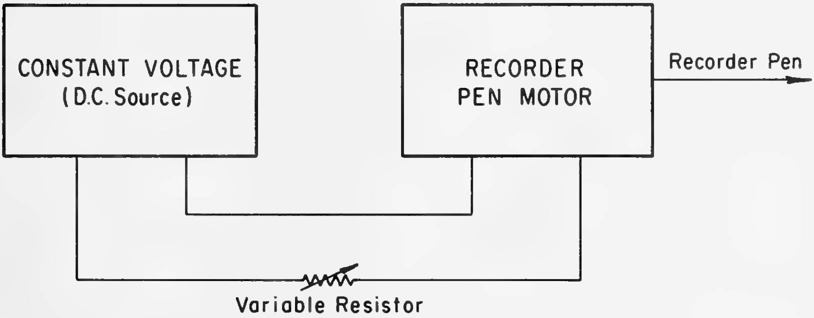

Figure 5. Series-Type, Step-Resistance Gage for Fresh Water

The recorder penmotor is essentially the same as an ordinary D'Arsonval panel-meter movement with a capillary, ink pen substituted for the indicating pointer. The components (magnet, moving coil, springs, etc.) are significantly larger and more rugged than the ordinary meter movement.

The variable resistor used in a gage consists of several fixed resistors in series with contact tips connected to the resistor junctions. The contact tips are molded into long epoxy resin shapes that allow the contact tips to be exposed. The number of contacts submerged by the part of the gage that is under water forms the variation in resistance.

The constant voltage d.c. source is obtained from a transformer, rectifier, filter, and voltage regulator operated from a 115-volt, 60-cycle power line. The output voltage from these components is constant even though the input line voltage may vary from about 95 to 130 volts and thus prevents the recorder penmotor from changing with a varying line voltage.

Since the voltage source is constant and the resistance of the penmotor is constant (neglecting temperature changes), the current in the circuit will increase if the value of the variable resistor is decreased. Ohms law, $E = IR$, applies.

The recorder penmotor is designed to provide a linear pen movement with a linear change in input current.

The nominal current required to move the penmotor pen through a 50-millimeter arc (full scale) is 20 milliamperes. The penmotor has a nominal internal resistance of 1,500 ohms, thus by ohms law the constant voltage source will be a nominal 30 volts (E = IR; .02 x 1,500 = 30 volts) for the required pen movement.

To make the penmotor move in equal increments from a variable resistor made of several resistors connected in series as shown in Figure 6, it is necessary to calculate each individual resistor value.

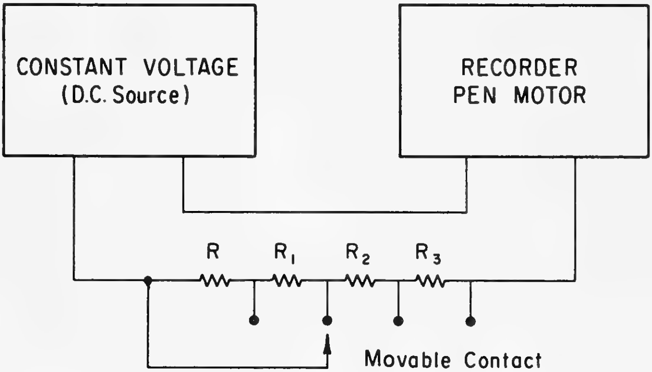

Figure 6. Series-Type, Step-Resistance Gage for Fresh Water.

Assuming a wave gage with 20 equal measurement increments and a penmotor with an internal resistance of 1,500 ohms that requires 20 milliamperes for full-scale movement and that indicates linearly with a change in current, then to move the pen full scale, 20 current changes of 1 milliampere each would be required. A 30-volt power source would provide full-scale penmotor movement.

$$\frac{30 \text{ volts}}{1{,}500 \text{ ohms}} = .02 \text{ amperes}$$

The first of the 20 intervals of gage measurement would reduce the 20-milliampere penmotor current by 1 milliampere.

To calculate the first gage resistor:

$$\frac{30 \text{ volts}}{19 \text{ milliamperes}} = 1{,}579 \text{ ohms.}$$

1,579 ohms total circuit resistance minus 1,500 ohm penmoter resistance = 79 ohms (first resistor).

To calculate the second resistor value:

$$\frac{30 \text{ volts}}{18 \text{ milliamperes}} = 1{,}667 \text{ ohms} - 1{,}579 = 88 \text{ ohms.}$$

To calculate the third resistor:

$$\frac{30 \text{ volts}}{17 \text{ milliamperes}} = 1{,}765 \text{ ohms} - 1{,}667 \text{ ohms} = 98 \text{ ohms.}$$

Such calculation shows that the resistors will not be of equal value to obtain equal increments of pen movement. The individual resistor values will be higher at the left and lower on the right side of the resistor string in Figure 6.

The circuit in Figure 6 applied to a practical circuit for measuring wave heights in fresh water is shown in Figure 7.

The major difference between the two circuits (Figures 6 and 7) is that the water path is now used to activate the changes in the variable resistor. Another change is the addition of a variable calibration resistor to adjust for differences in the conductivity of fresh water and differences in penmotors. Analysis of this circuit shows that the bottom resistor in the gage circuit is connected to the ground rod. This connection is necessary due to the electrical resistance of the residual water path on the epoxy resin when the gage submergence is small. Further analysis of the circuit shows that the water path has a resistance of its own, therefore, some current will flow from each submerged metal sensing tip to the ground rod; such flow will aid in reducing the effective resistance of the water path.

Using the 30-volt source previously calculated as required to provide full-scale penmotor operation in the practical gage circuit in Figure 6, it is found that the recorder penmotor will not rise to full scale. This is due to the added resistance of the water path. To compensate for the increased resistance, it is necessary to increase the voltage from the constant d.c. voltage source. The increased resistance path will also change the direct logic used for Figure 6 in calculating the resistors for the gage.

Design experience has resulted in the selection of a d.c. voltage source of 46 and 54 volts as the best value for most fresh-water applications. This same experience has resulted in the resistor values shown in Tables I and II for 20- and 25-foot series-type gages. If a 10-foot gage is desired, it is recommended that the spacing of the sensing tips be used to 0.1 foot and the resistor values for the 20-foot gage be used.

There will be some electrolytic action in the water path due to the use of direct current. This action usually causes a hard powder to form on the lead sensing tips of the gage. Rate of coating formation depends on the mineral content of the local water. The gage must be cleaned of the deposit to obtain the most accurate operation. Frequency of cleaning

Text resumes on page 16

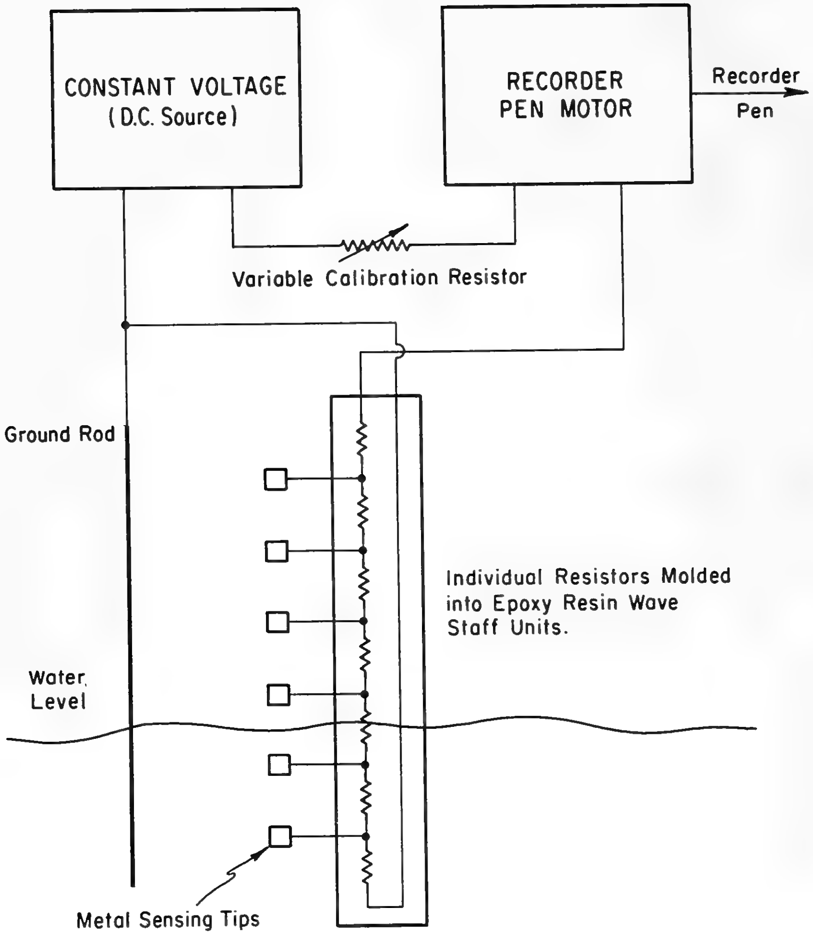

Figure 7. Practical circuit for measuring wave heights in fresh water.

TABLE I

RESISTANCE VALUES IN OHMS FOR 20-FOOT GAGE FOR FRESH WATER

Top Section A	Section B	Section C	Bottom Section D
24	41	83	267
24	41	87	286
24	42	90	305
25	43	93	326
26	45	96	351
26	45	101	377
26	47	104	408
27	48	109	441
28	50	113	480
28	50	118	522
29	53	123	572
29	53	129	629
30	55	134	695
30	57	141	771
31	59	147	861
32	60	155	968
33	62	162	1096
33	64	171	1251
34	67	179	1441
35	68	189	1678
36	70	200	1980
37	73	210	2370
38	75	224	2888
38	78	236	3598
39	81	252	4606
762 T	1427 T	3646 T	28,067 T

TABLE II

RESISTANCE VALUES IN OHMS FOR 25-FOOT SERIES GAGE

No.	Top Section A	Section B	Section C	Section D	Bottom Section E
1	22	33	55	110	324
2	21	34	56	115	343
3	23	34	59	118	365
4	23	35	59	123	387
5	24	36	61	128	412
6	23	36	62	131	441
7	25	37	64	137	471
8	24	38	66	142	504
9	25	38	67	147	543
10	25	39	70	154	585
11	26	40	71	159	632
12	26	41	73	166	686
13	26	42	75	173	746
14	27	42	77	180	814
15	27	44	79	188	894
16	28	44	81	197	983
17	28	45	84	205	1089
18	29	47	87	215	1212
19	29	47	88	226	1357
20	30	48	92	236	1530
21	30	50	95	249	1738
22	31	50	97	261	1961
23	32	51	101	275	2334
24	32	53	103	291	2698
25	32	55	108	306	3201
					26,250

TABLE III

COMPONENTS FOR 25-FOOT FIVE-SECTION FRESH-WATER SERIES-RESISTANCE GAGE

1.	Strip-Chart Recorder Brush #RD-2321-00. Order with following modifications: single channel operation with 50 mm chart width. Old style penmotor #BL 902 and long pen #BL 921.	1 ea.
2.	Chart rewind Brush #RA-2402-10	1 ea.
3.	Constant voltage power supply 48-52 volts 100 MA Technipower #M-50.0 - 0.100, or equal.	
4.	Toggle Switch SPST AH&H #20994-BF	2 ea
5.	Potentiometer 1.5K Mallory #M1.5MPK, or equal	1 ea.
6.	Potentiometer 2K Mallory M2MPK, or equal	1 ea.
7.	Relay Potter Brumfield #KR 11AG, or equal	1 ea.
8.	Plug amphenol #80 PC2F, or equal	2 ea.
9.	Plug amphenol 80 MC2M	2 ea.
10.	Cord set Belden 17408-SJ, or equal	3 ea.
11.	Binding post, Superior type DF30 black	1 ea.
12.	Binding post, Superior Type DF 30 red	1 ea.
13.	Aluminum chassis Bud #AC-411, or equal	1 ea.
14.	Time switch Tork Hourmaster #4100, or equal	1 ea.
15.	Socket amphenol #160-10	3 ea.
16.	Epoxy resin Scotchcast #2	42 lbs.
17.	Precision Resistors Wirewound 190 type TX 2212 Precision Resistor Co. 109 U.S. Highway, Hillside, N.J., (see Tables I and II).	125 ea.
18.	Cable 2-conductor #20 AWG with 2 High-strength steel members. Neoprene outer sheath. Marsh & Marine Co. Houston, Texas, Type #TPSC, or equal.	110 ft.
19.	Bar solder 50/50 tin-lead for lead sensing tips	6 lbs.
20.	Bare copper wire tinned #18 AWG	50 ft.
21.	Cable 2-conductor #16. Length as required to connect wave staff site to recording site.	

NOTE: Steel "H" beam is needed for holder for epoxy gage sections.

must be determined locally for each gage. Reversing the two electrical leads connected to the wave staff will reverse the polarity of the voltage to the staff, and may aid in changing the electrolytic action, and extend the periods of operation between cleanings.

The lead sensing tips of the epoxy gage sections are extended from the main body of the section to increase the insulating distance provided by the epoxy resin between the sensing tip and the metal gage mount. This increased distance helps to increase the resistance value of the water film remaining on the epoxy resin after a wave crest has passed, thus providing the desired stepped resistance change by the rising and falling action of the water during wave action.

The penmotor will move in proportion to the stepped resistance changes in the wave staff, and will provide a profile of the water surface against time on the moving strip-chart on the recorder.

The series-resistance gage will operate most accurately in locations where small changes occur in the mineral content of the water. If the gage is operated during conditions where great changes in mineral content occur, such as during periods of large snow runoff, the gage calibration should be checked during such conditions, and the recordings corrected as necessary.

2. Fabrication of Series-Type, Step-Resistance Gage

Most of the parts needed for fabrication are listed in Table III. The desired number of epoxy gage sections are molded as shown on Figure 8. Cables for each section should be long enough to allow submerging all gage sections at one time while working from the top of the gage mount. This will allow operating personnel to calibrate the gage at regular intervals. The top gage section has the lowest resistor value between the top plug and the second plug. Resistors increase in value from the top of the gage toward the bottom, the highest value of resistance being between the bottom plug and the connecting conductor molded into the gage.

The power supply requires the small aluminum chassis and the parts indicated on Figure 9. Layout of the power supply is not critical, use of good shop practice is all that is required. The voltage-adjust control on the constant voltage power module must be available for adjustment.

Three 115-volt receptacle plugs, one line cord and one toggle switch are installed in the sides of the timer. These items are installed and wired as shown in Figure 10.

The strip-chart recorder listed in the parts list (Table III) for this gage has a minimum chart speed of about 12 inches per minute. To save chart paper, the recorder can be modified for a chart speed of 6 inches per minute. This modification is recommended and is outlined in Section VIII. A connecting cable to this recorder from its input signal connector is made in the desired length using 2-conductor No. 18 cable as shown on Figure 11.

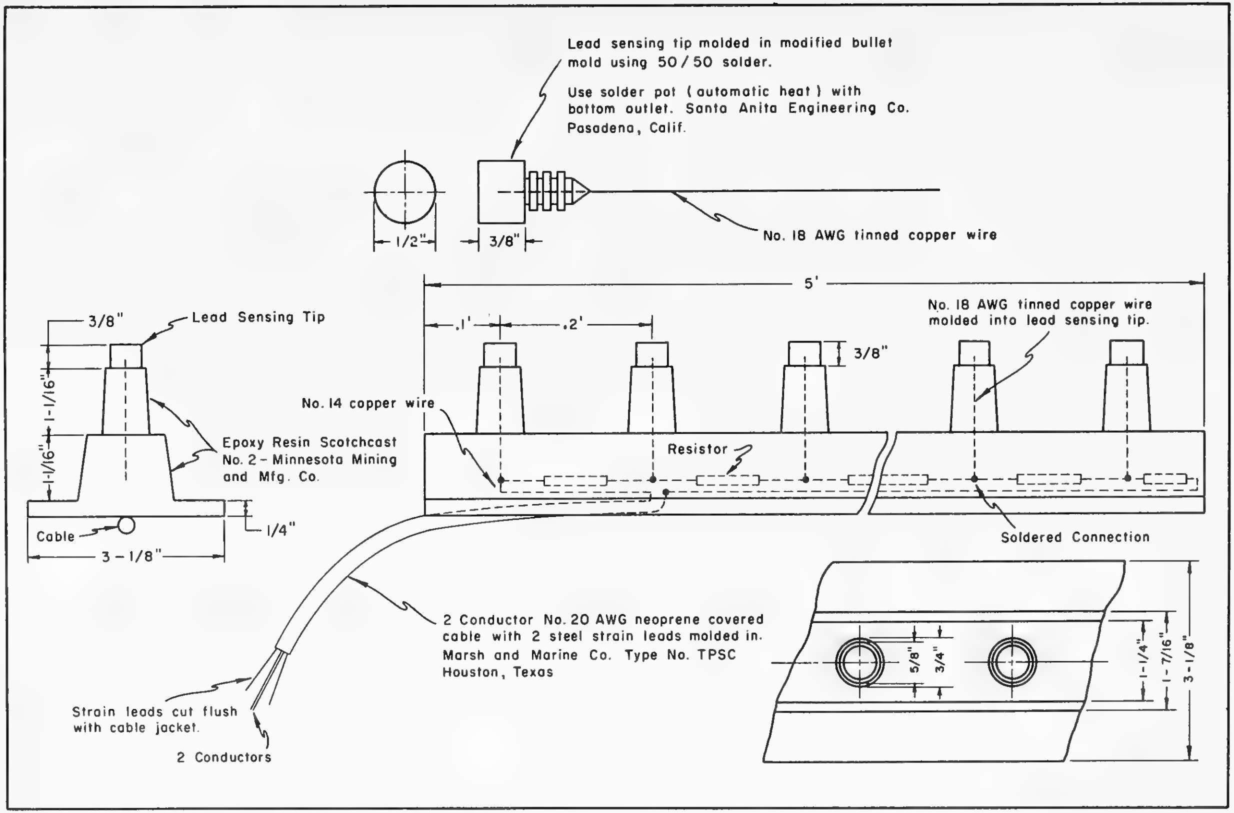

Figure 8. Series-Type Step-Resistance Wave Gage for use in Fresh Water.

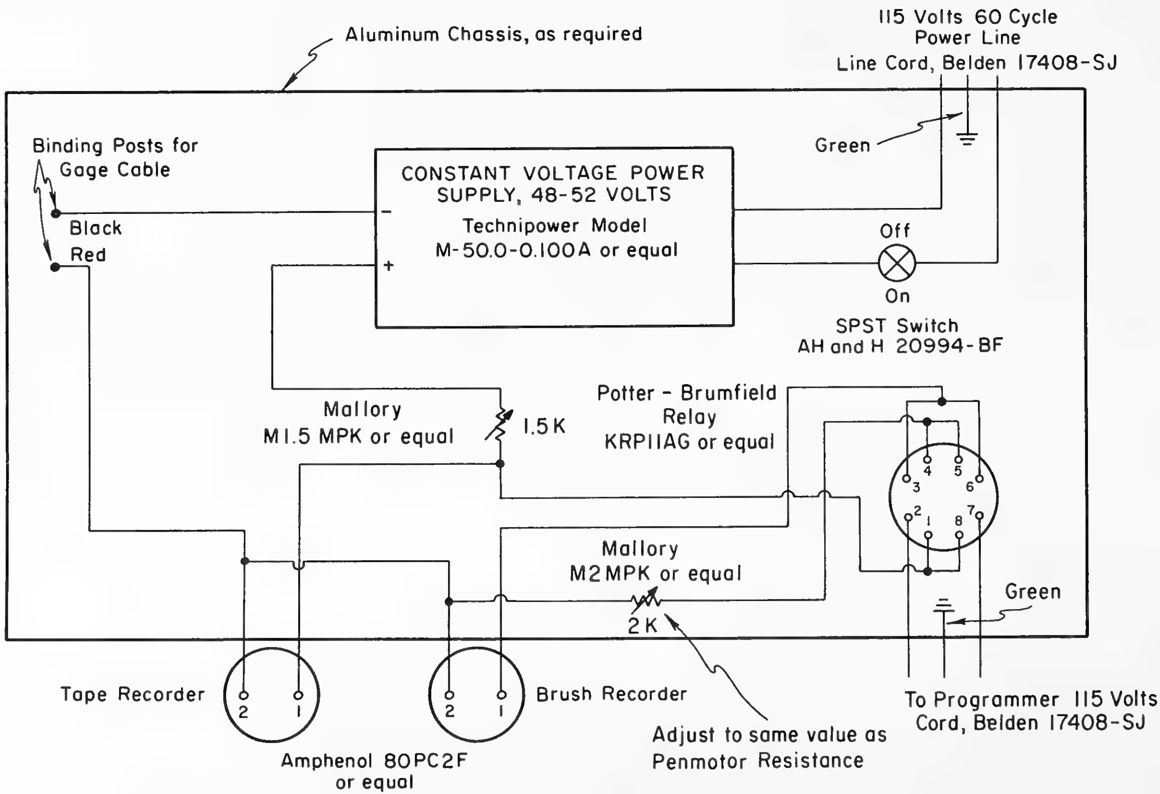

Figure 9. Power unit for Fresh-Water Staff Gage.

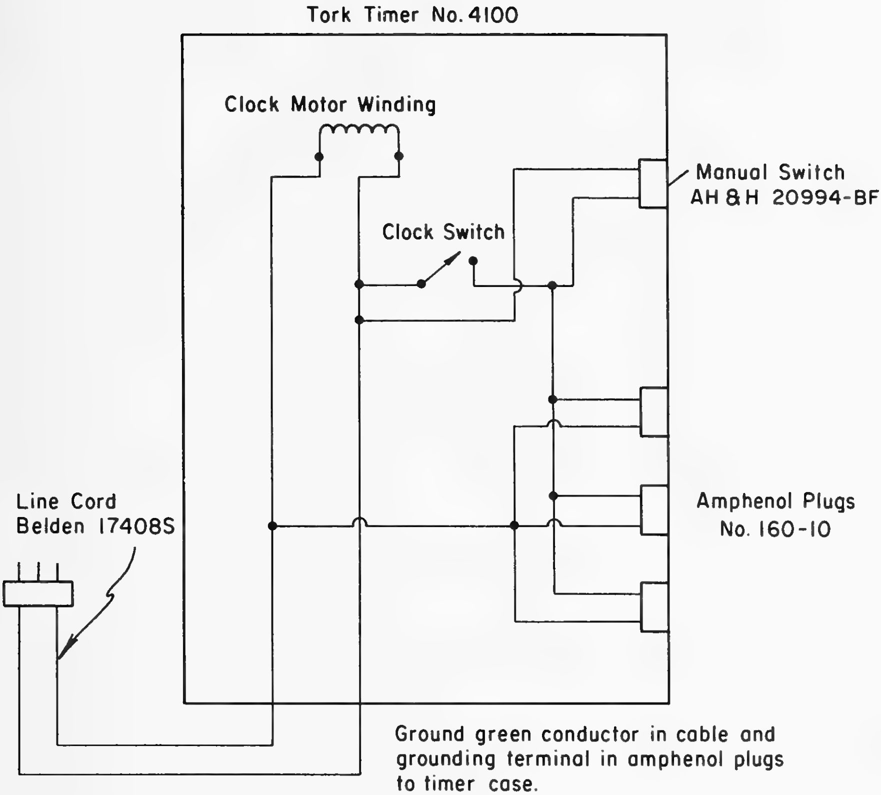

Figure 10. Programmer for Wave Gages. Plugs and switch to be mounted in right side and bottom of case as mechanically feasible. (Do not mount on lid.)

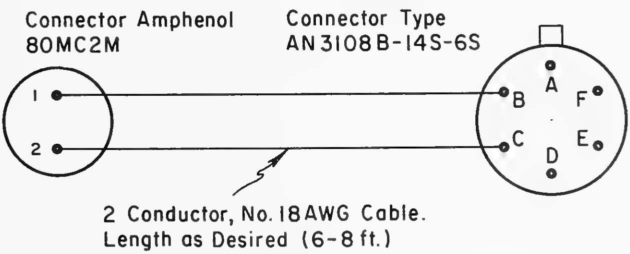

Figure 11. Signal Input Cable for Strip-Chart Recorder.

The metal wave-gage holder is fabricated to the desired length as shown in Figure 12; a list of components used in fabrication is shown in Table IV. Mounting brackets for attaching the holder to the supporting structure should be strong enough to support the holder during severe wave conditions. Figure 13 outlines one type of bracket that has been used in supporting the gage holder on a vertical piling. The gage holder gets two coats of zinc chromate primer and two or three coats of anti-fouling paint as used on ship bottoms. Government agencies may use this paint which is available through Government Services Administration (GSA) supply - Stock No. GS8010-550-8305 for the primer and Stock No. GS8010-290-6651 for the anti-fouling paint. DO NOT PAINT THE GROUND ROD. Install the ground rod after the gage holder has been installed. The holders should be installed so that about 6 to 8 feet are below mean lower low water, 17 to 19 feet out of the water.

Only the epoxy wave gage sections that are below or at the water line require anti-fouling paint. Mold release must be removed from the gage sections prior to painting. DO NOT PAINT THE LEAD SENSING TIPS.

3. Operation of a Series-Type, Step-Resistance Wave Gage

a. Installation

When placing the epoxy wave gage sections in the gage holder, the section having the highest value resistors is the bottom section, and goes into the holder first. The section with the next highest value resistors is placed in the holder on top of this section, and so on until the section having the lowest value of resistors is in the top of the gage holder.

The power unit, the strip-chart recorder, program clock, magnetic tape recorder (if used) and chart rewinder are connected as shown on Figures 14 and 15.

b. Calibration

The accuracy of the recorded wave heights will depend directly on the accuracy of the calibration of the gage. There will be enough difference in each wave gage and in each strip-chart recorded to require that each gage be individually calibrated.

The ideal calibration would be raising and lowering the gage holder with the gage sections into the water in small increments and marking the strip-chart recorder with each move. Usually, lack of water depth, the manual process required, and the presence of wave action prevent such calibration.

If many gages are to be calibrated, it may be desirable to provide a cistern-like basin about 24 inches in diameter with the required depth. A wave gage holder would be a permanent part of the calibration pit. Such

a pit should be made of concrete pipe or other nonconducting material; use of a metal wall would cause an inaccurate calibration of the gage.

The procedure outlined below has been satisfactorily used for calibration of staff-type gages. If feasible, a time of low-wave action should be selected for the calibration.

If possible, the sections that are to be removed from the water first are kept inside the steel gage holder. This provides a more accurate gage calibration. If the water is deep enough, place two or three of the sections in the holder in the order that they are used in the gage. The section having the lowest value of resistors is on top, and the succeeding sections are below it. When the section having the lowest value of resistors has been removed from the holder (in the desired calibration increments), the other gage sections in the holder should be removed, and a succeeding section should be put in the bottom of the mount, thus all sections having the lowest resistors will be removed from inside the gage holder in succession during the calibration process.

Calibration of the gage proceeds as follows:

a) If a magnetic tape recorder is used, calibrate it with the strip-chart recorder as outlined in Section VII.

b) Turn the strip-chart recorder "on-off" switch to "off".

c) Turn the "off-on" power switch on the power supply unit to "on".

d) Remove all epoxy wave gage sections from the metal gage holder.

e) Turn on the strip-chart recorder using the switches on the recorder and on the programmer.

f) Using the mechanical lever on the recorder penmotor, adjust the recording pen to the left side of the chart paper.

g) Place the epoxy gage sections under water being careful to keep the lead tips adjacent to the metal gage holder with about the same spacing from the ground rod as they would have been installed in the gage holder.

h) Adjust the calibration resistor on the power unit to provide full-scale reading on the strip-chart recorder.

i) Remove all wave gage sections from the water.

j) Repeat steps f, g, h, and i until *zero* and *full scale* are obtained.

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TABLE IV

LIST OF COMPONENTS FOR WAVE-GAGE HOLDER (FIVE-SECTION, 25-FOOT GAGE)

1.	Steel "H" Beam 4" x 4" WF-13 pounds per foot, 25 feet long	1 each
2.	Steel rod 1/2" diameter 25 feet long, hot rolled	5 "
3.	Steel rod 3/8" x 1/2", 25 feet long, hot rolled	2 "
4.	Steel rod 3/8" x 1/2", 10 feet long, hot rolled	1 "
5.	Steel rod 1/2" x 1/2", 20 feet long, hot rolled	1 "
6.	Steel plate 3/8" x 6" 20 feet long, hot rolled	1 "
7.	Steel plate 1/2" X 8", 3 feet long, hot rolled	1 "
8.	Steel bar 1" x 3", 7" long, hot rolled	1 "
9.	Steel bar 1" x 2", 4" long, hot rolled	1 "
10.	Cap screws, type 316 stainless steel, 5/8" x 6" long, 11 threads per inch Hex head	10 "
11.	Cap screw, type 316 stainless steel, 5/8" x 1 3/4" long 11 threads per inch Hex head.	20 "
12.	Cap screw, type 316 stainless steel 5/8" x 3 1/2" long	17 "
13.	Lock washer, type 316 stainless steel for 5/8" bolt	45 "
14.	Nuts, type 316 stainless steel, 5/8" regular, 11 threads per inch, Hex head.	45 "

NOTE: Mounted to 8-inch Steel "H" beam pile as supporting structure.

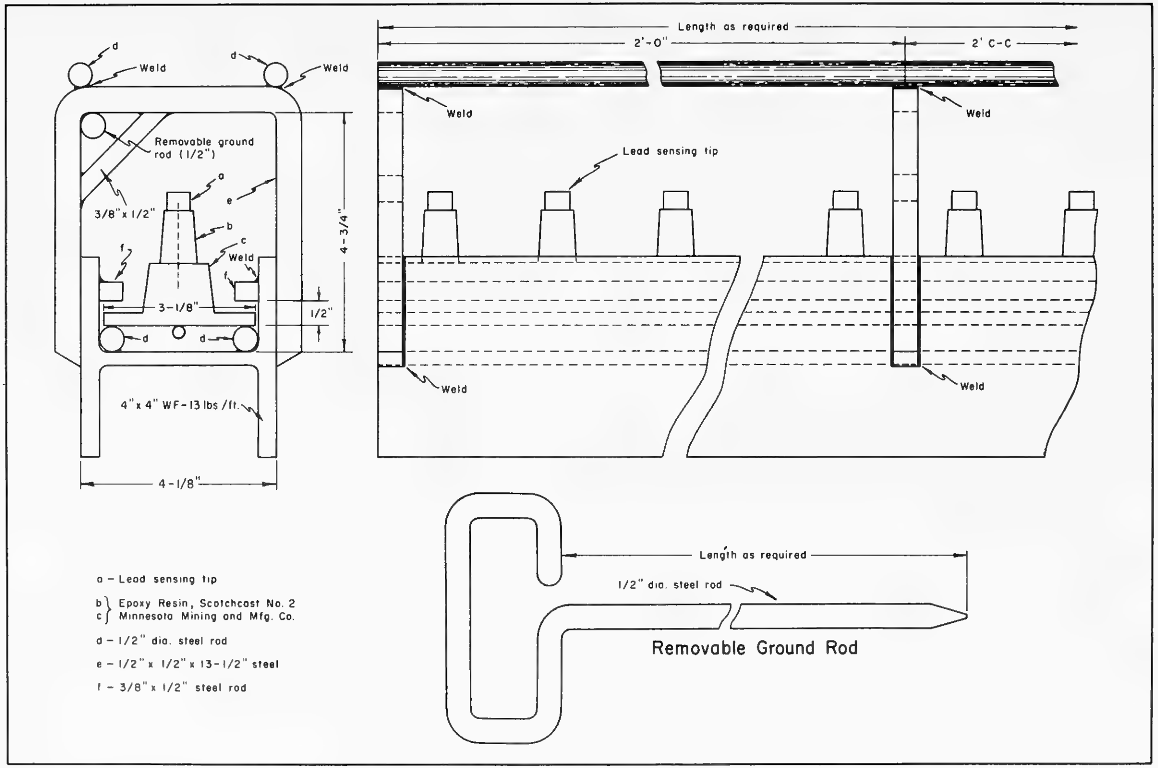


Figure 12. Holder for sectional step-resistance gage sections.

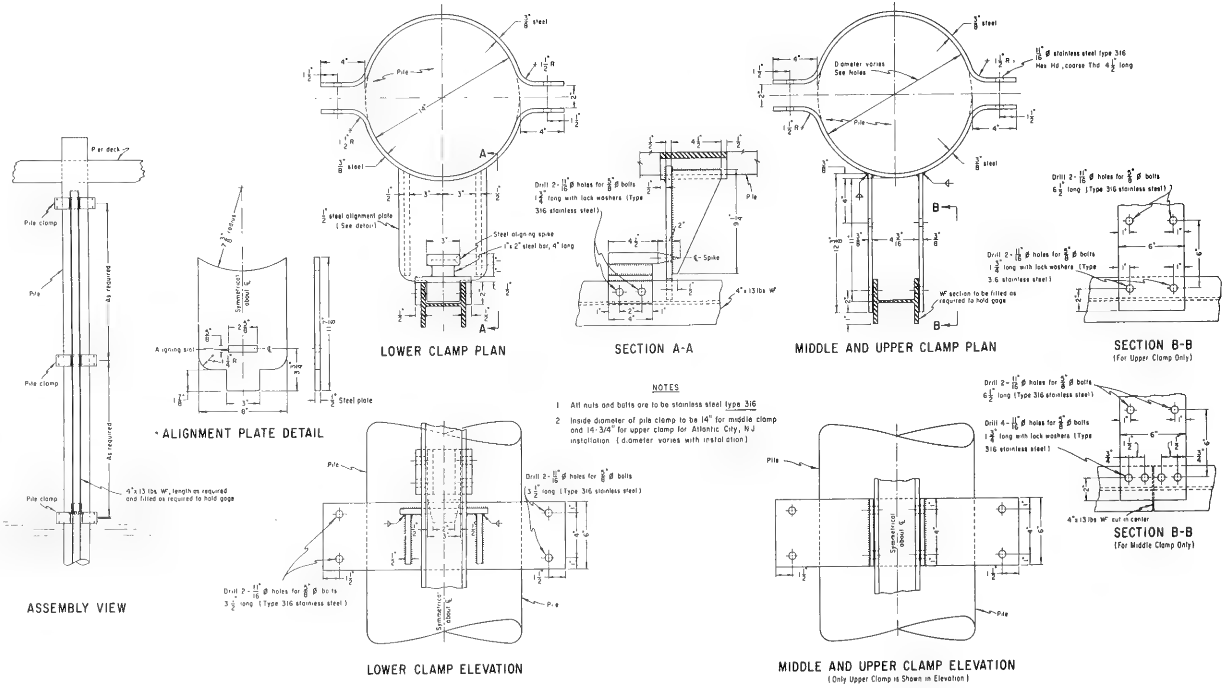
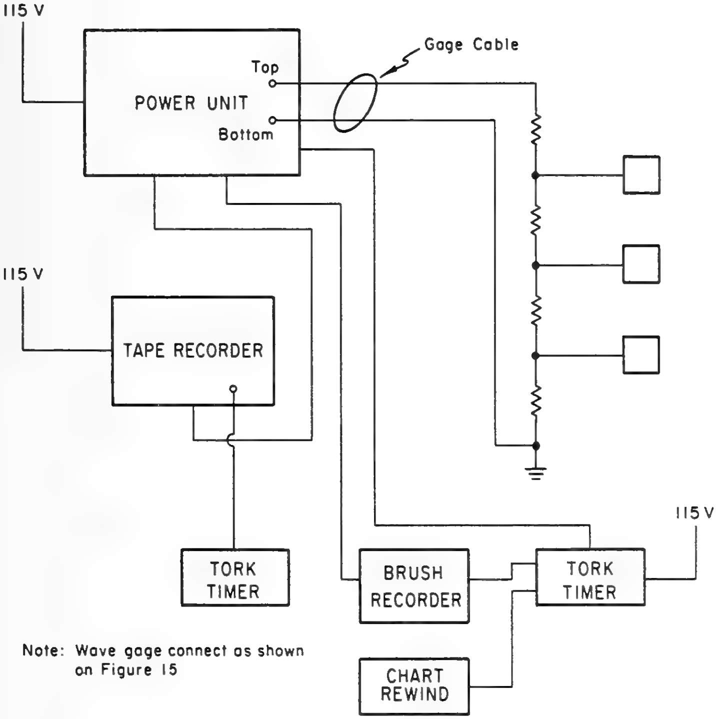


Figure 13. Pile Clamp for Wave Gage



Note: Wave gage connect as shown on Figure 15

Figure 14. Diagram of Fresh-Water Staff Gage.

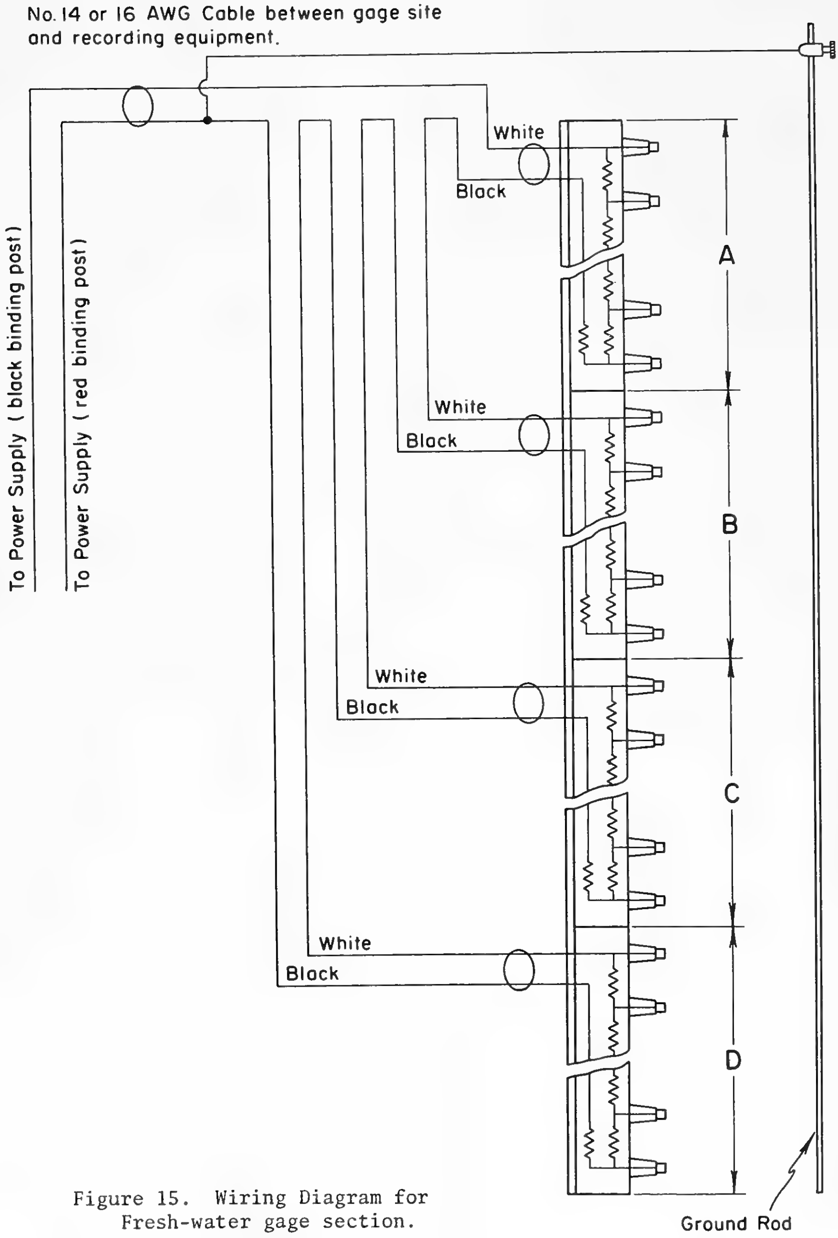


Figure 15. Wiring Diagram for
Fresh-water gage section.

k) Place all gage sections in water and remove the top gage section from the water 1 foot at a time, and mark the strip-chart accordingly. Continue with the remaining gage sections.

l) Check the strip-chart record for linearity.

m) If the chart is not linear, change the voltage out of the d.c. power module to 52 volts.

n) Repeat steps g, h, i, j, k, and l. A change in linearity should be found in the strip-chart recording. If linearity has improved, continue increasing the voltage in small increments and repeating steps g, h, i, j, k, and l until the desired linearity is obtained. If the linearity is worse, reduce the voltage in small increments and proceed with steps g, h, i, j, k, and l until good linearity is obtained.

o) Turn off the strip-chart recorder using the switch on the programmer.

p) Set the programmer to the desired recording program using screws in the program dial to provide a recording beginning at the selected hour or hours and for the selected number of minutes.

q) Place the epoxy gage sections in the metal holder.

r) Place magnetic tape recorder in operation.

s) Gage is now in operation.

c. Maintenance

Maintenance of the gage involves changing the paper chart, refilling the ink reservoir, and checking the program units for proper timekeeping.

The epoxy gage sections and the metal holder will require cleaning; frequency of cleaning will depend on local conditions.

The lead tips on the epoxy sections will possibly grow a covering that looks like a hard powder. This covering will affect the gage accuracy and must be removed; use of sandpaper or steel wool may be required. Reversal of the leads connecting the gage sections to the power supply sometimes changes the rate of covering, and may be tried if desired.

Servicing of the recorders and programmers should follow instructions in the manufacturer's manuals.

Section III. PARALLEL-TYPE, STEP-RESISTANCE GAGE FOR SALT WATER

1. Theory of Operation of Parallel-type, Step-Resistance Gage

Due to the low resistance path created by a film of salt water on the epoxy wave gage sections, the gage design for fresh water cannot be used in the ocean. To compensate for the low-resistance, salt-water film and the increased electrolytic action in salt water, it is necessary to provide low resistance values in the wave staff and to use alternating current and low voltage in the sensing circuit. The circuit in Figure 16 was evolved to permit the use of low-voltage, low-value resistors, and alternating current in the wave-sensing circuit. Analysis of this circuit (Figures 16 and 17) shows that a standard 115-volt, 60-cycle line is connected to a constant-voltage transformer. The output of the transformer is a constant 115 volts ± 1 percent for powerline variations between 95 and 130 volts. This removes variations in the record that might be caused by a change in line voltage. Output of the constant-voltage transformer is applied to an autotransformer which provides a means for varying the voltage applied to the wave-gage circuity. This feature of voltage adjustment permits calibrating the wave gage for full-scale indication on the strip-chart recorder. A voltmeter is used to monitor the voltage out of the autotransformer.

The selected voltage from the autotransformer is connected to a stepdown transformer which further reduces the line voltage to a value suitable for wave-sensing resistors. The stepdown transformer also isolates the powerline from the wave staff. The secondary winding of the stepdown transformer is connected in series with the variable-resistance circuit provided by the parallel-resistor, water-conducting path, and the primary winding of a step-up transformer. The step-up transformer is identical to the stepdown transformer except that its windings are used in a reverse manner.

Output voltage from the step-up transformer is applied to a bridge rectifier and low-pass filter to convert the varying amplitude (caused by changes in water level) of the 60-cycle a.c. source to a d.c. signal suitable for driving the recorder penmotor. The stepdown, step-up transformer units and the rectifier-filter unit have fixed resistors incorporated in them to aid in getting a linear signal from these units.

This circuit utilizing the parallel resistance circuit of the wave staff and the low-voltage windings of the stepdown, step-up transformers is a low-voltage, current-sensitive circuit. Such a circuit must have low resistance electrical connections. It is mandatory that the step-up, stepdown transformers be placed physically close to each other and as near as possible to the wave gage staff sections.

Design experience has evolved the resistor values for gages of 20 and 25 feet as listed in Table V. These values operate with the other electrical components listed in Table VI, and should provide a gage with good operational features and good linearity. Changes in components or resistor values may cause nonlinear gage response, and require circuit modifications.

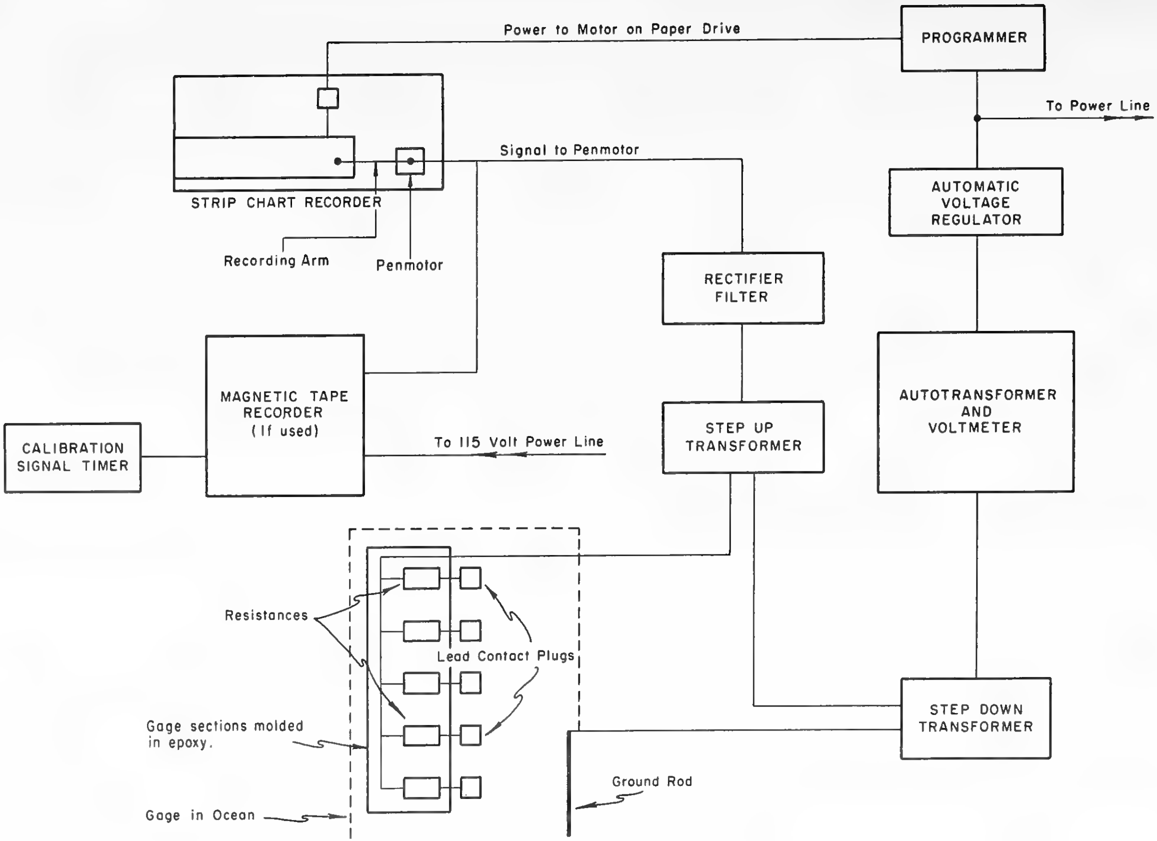


Figure 16. Functional Block Diagram of Parallel-Type, Step-Resistance Gage for Salt Water.

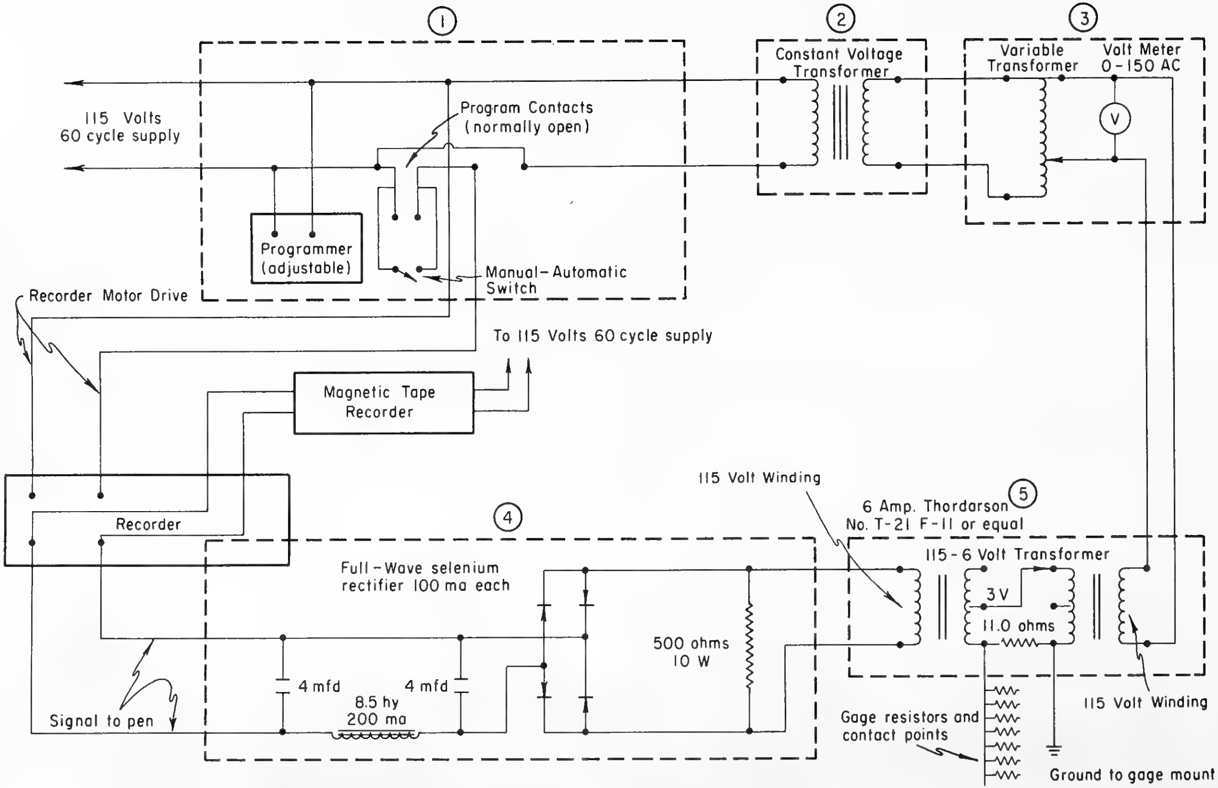


Figure 17. Functional Diagram for Parallel Resistor Gage.

TABLE V

RESISTOR VALUES FOR SALT-WATER PARALLEL STEP-RESISTANCE WAVE GAGE

For 20-foot gage			For 25-foot gage		
18.3 Ohms		5 each	9.9 Ohms		5 each
20.4 "	Top Section	5 each	11.0 "	Top Section	5 each
22.6 "		5 each	13.0 "		5 each
24.7 "		5 each	14.7 "		5 each
26.9 "		5 each	16.5 "		5 each
29.0 "		5 each	18.3 "		5 each
31.2 "		5 each	20.4 "		5 each
33.4 "		5 each	22.6 "		5 each
35.6 "		5 each	24.7 "		5 each
38.0 "		5 each	26.9 "		5 each
40.2 "		5 each	29.0 "		5 each
43.1 "		5 each	31.2 "		5 each
45.4 "		5 each	33.4 "		5 each
47.6 "		5 each	35.6 "		5 each
50.3 "		5 each	38.0 "		5 each
52.9 "		5 each	40.2 "		5 each
55.6 "	Bottom Section	5 each	43.1 "		5 each
58.8 "		5 each	45.4 "		5 each
62.1 "		5 each	47.6 "		5 each
65.8 "		5 each	50.3 "		5 each
			52.9 "		5 each
			55.6 "	Bottom Section	5 each
			58.8 "		5 each
			62.1 "		5 each
			65.8 "		5 each

TABLE VI

COMPONENTS FOR FIVE-SECTION 25-FOOT PARALLEL RESISTANCE GAGE FOR SALT WATER

1.	Programmer, Tork Hourmaster Model 4100	1 ea.
2.	Voltage Regulator, Sola Type 20-13-030-1 input 95-130 volts, output 118 volts 30 VA.	1 ea.
3.	Variable transformer, Superior Electric Co. Model 10B, input 120 volts, single phase, 60 cycles output 0-132 volts 2.25 amps.	1 ea.
4.	a.c. voltmeter 0-150 volts, Triplett Model 337-S	1 ea.
X 5.	Filament transformer Thordarson No. T21F11 6.3 volts c.t. 6 amperes.	2 ea.
X 6.	Precision Resistors, wire wound, 1% Type TX-2212, manufactured by Precision Resistor Company, 109 U.S. Highway, Hillside, N.J. Values shown in Table V.	125 ea
7.	Scotchcast Resin #2, Minnesota Mining & Manufacturing Co.	42 lbs.
8.	Bar Solder, 50% tin, 50% lead.	6 lbs.
9.	Wire solid copper, plastic insulation AWG #14	25 ft.
X 10.	Resistor, 500 Ohms, 10 watt	1 ea.
X 11.	Selenium rectifier, International Rectifier #Q4B, 130V RMS, 100 MA	4 ea.
X 12.	Capacitors, Sprague 155 P-156P Metallized-paper Tublar 4.0 mfd. 200 volts.	4 ea.
X 13.	Filter choke, Stancor C 1721 8.5 Henrys 200 MA.	1 ea.
14.	Box-Mounting receptacle Bendix Scinflex, RB 3102 #10-42214-2P Scintilla Division, Bendix Aviation Corp., Sidney, N. Y.	1 ea.
15.	Plain Gasket, used with box-mounting receptacle, Bendix Scinflex #10-40450-14	1 ea.
16.	Straight plug, Bendix Scinflex RB-3106 #10-42614-2S with #10-40908-141 back shell and #10-40457 Hex coupling nut and #AN-3057-6B cable clamp.	1 ea.
17.	Box, aluminum watertight 4 1/2" D x 6 1/2" W x 6 1/2" H Adalet #JP102, A Adalet Mfg. Co. Cleveland, Ohio.	1 ea.

TABLE VI (continued)

18.	Utility box, metal 5" D x 6" W x 9" H. Black Crackle finish - Bud #CU 1099B.	2 ea.
19.	Switch SPST, Arrow Hart & Hegeman #20994BF	1 ea.
20.	Chart rewind, Brush Model #RA-2402-11	1 ea.
21.	Strip-Chart Recorder Brush Model No. RD-2321-00 (order with following modifications: single channel operation and 50 mm chart width. Old style penmotor #BL 902 and Long Pen #BL 921.	1 ea.
22.	Wire solid copper, bare, tinned, AWG #18	50 ft.
23.	Cable 2-conductor #20 AWG with 2 high-strength 1 1/6" steel members. Neoprene outer sheath Marsh and Marine Mfg. Co., Houston, Texas, Type #TPSC.	110 ft.
24.	4-conductor #14 AWG rubber covered. Length required to connect wave staff site to recording site.	
25.	Plug amphenol #160-10	3 ea.
26.	Line cord a.c. Belden 17408-S	3 ea.
X 27.	Resistor, 11 Ohms 1% tolerance 10 watts IRC #AS-10	1 ea.
28.	Connector, male cable plug Amphenol type #80-MC2M	2 ea.
29.	Connector, female receptacle, Amphenol type #80 PC2F	2 ea.
30.	Relay DPDT, 115 volt, 60 cycles Potter Brumfield KRP 11AG	1 ea.
31.	Potentiometer 2K-Ohms Mallory M2MPK, or equal	1 ea.
32.	Solder, 18 S.W.G. 60% tin/ 40% lead	1 lb.
33.	Socket, Octal, Amphenol #78RS8	1 ea.
34.	Connector, female 3-wire polarized type Harvey Hubbell "Twist Lock" #7484.	1 ea.
35.	Connector, male base 3-wire polarized type Hubbell #7486	1 ea.
36.	Connector, male cap, 3-wire polarized type Hubbell #7485	1 ea.
37.	Connector, female base, 3-wire polarized type Hubbell #7487	1 ea.
38.	Cable, electrical, rubber covered, three-conductor AWG #18 Belden type 8453	15 ft.
39.	Cord - Grip for rubber covered cable 0.500 - 0.625 diameter. aluminum, Pyle-National #DB-10	1 ea.
40.	Cable 2-conductor #18 AWG Belden #8452, or equal	12 ft.

NOTE: This list does not include gage mount.

The gage will operate in salt-water locations that have little or no change in salinity. If the gage is placed in locations having significant salinity changes, the wave record will vary in accuracy with the changes in salinity.

2. Fabrication of a Parallel Step-Resistance Gage

Fabricate the required number of 5-foot epoxy gage sections as outlined in Figure 18. The top gage section will have the lower value resistor connected to the top five sensing plugs, and the resistors will progressively go higher in value until the highest value of resistors are connected to the five sensing plugs, and the resistors will progressively go higher in value until the highest value of resistors are connected to the five sensing plugs on the bottom gage section. The cable from each wave gage section (molded as part of the section) should not extend more than 10 feet from the top of the gage mount. The resistance in the gage cables and leads from the transformer unit connected to the gage cables and leads from the transformer unit connected to the gage cables are part of a low-voltage, current-sensitive circuit. The resistance of these connections must therefore be low; long leads or high resistance connections in this circuit must be avoided in order to provide best gage linearity. Wire size in the cables molded into the gage sections should not be smaller than 2-conductor No. 20 AWG in parallel.

Fabricate the transformer unit as shown on Figure 19. Wire the transformer unit as shown on Figure 20. Be sure that all connections in this unit are well made and well soldered. This unit may be filled with a clear potting compound available from Dow Corning Company, their No. 182. If this unit is not filled, care should be taken to ensure that it is watertight.

Fabricate the voltage control, rectifier-filter unit, and programmer as shown on Figures 10 and 21 and wire as shown on Figures 10 and 22.

Strip-chart recorder chart speed may be modified, if desired, as outlined in Section VIII. Fabricate the signal connecting cable for the strip-chart recorder to the desired length using 2-conductor No. 18 AWG cable as shown on Figure 11.

Fabricate the metal gage holder to the required length shown in Figure 12. Suitable mounting brackets for the gage holder should meet local installation requirements. Mounting brackets must be strong enough to withstand the forces of wave action expected at the gage site. A bracket design that has been used on vertical piling is shown on Figure 13 which may serve as a guide.

Paint the gage holder with two coats of primer and two coats of any good commercial anti-fouling paint. Government agencies may use Government Services Administration GSA Stock No. GS8010-550-8305 and GS8010-290-6651, respectively. DO NOT PAINT THE GROUND ROD. Paint the gage sections that are below and at the water line with three coats of anti-fouling paint. Clean the sections of mold release prior to painting. DO NOT PAINT THE LEAD SENSING TIPS.

Text resumes on page 40

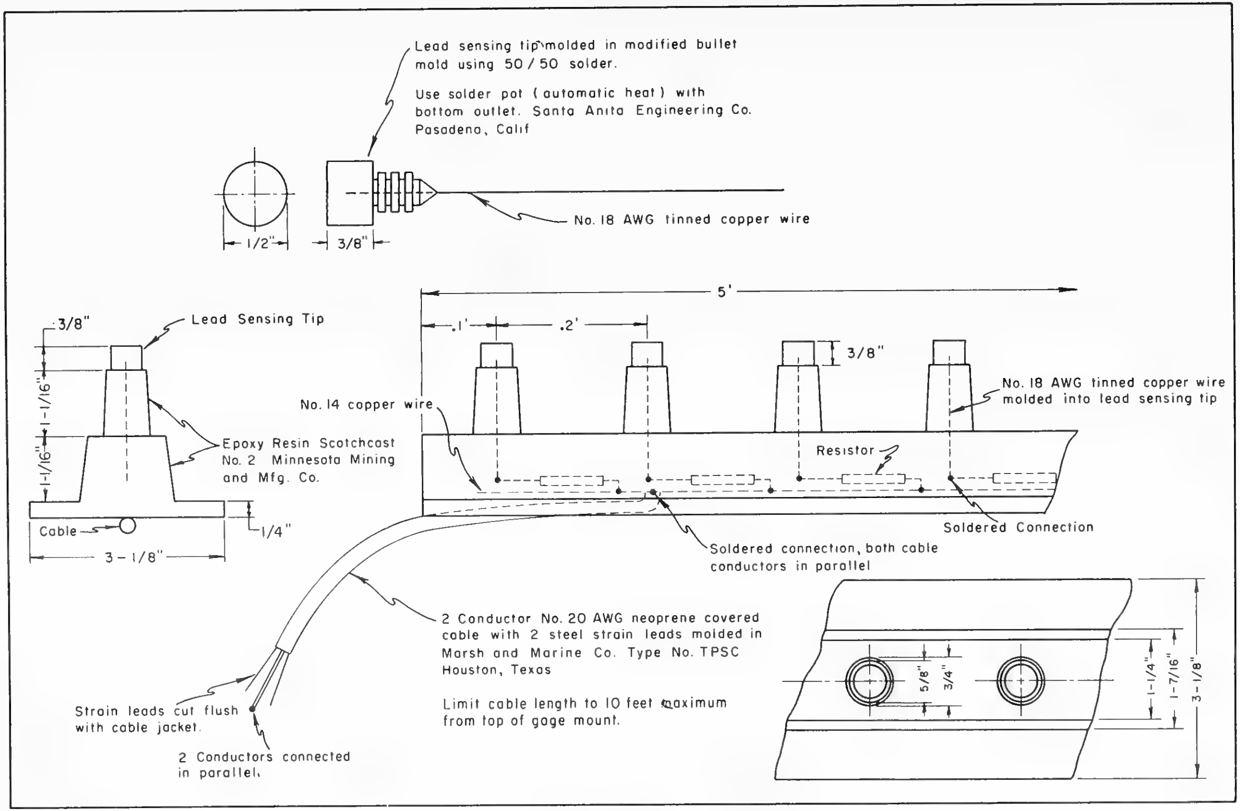


Figure 18. Parallel-type, Step-Resistance Gage for Use in Salt Water.

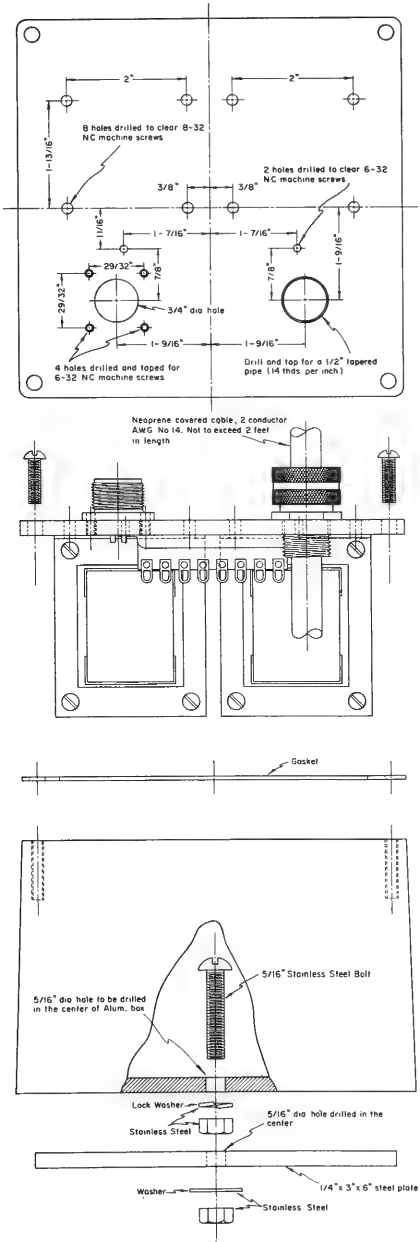


Figure 19. Transformer Unit for Salt-Water Gage

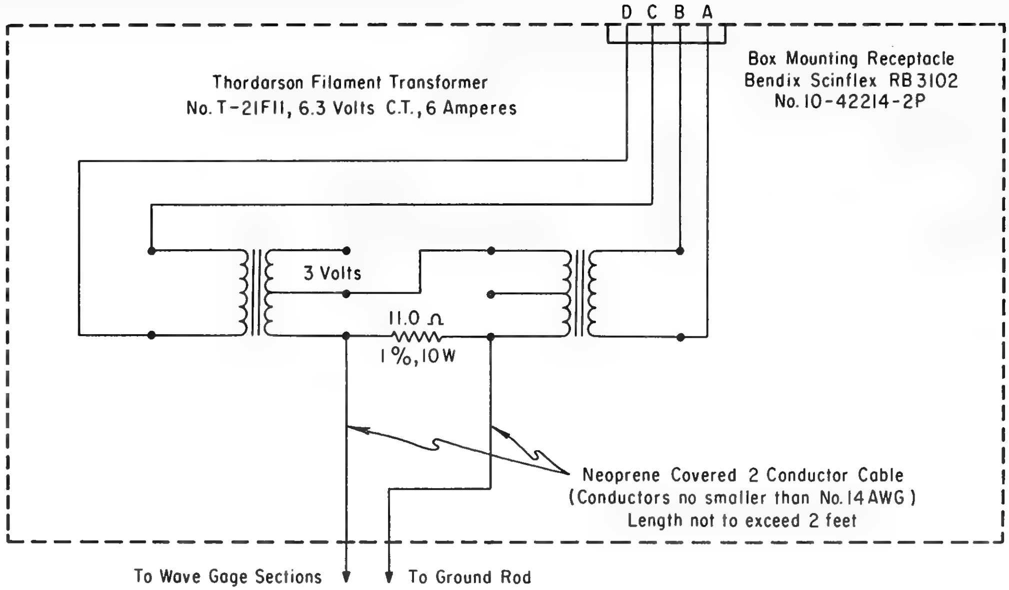


Figure 20. Wiring Diagram of Transformer Unit of Parallel Step-Resistance Gage

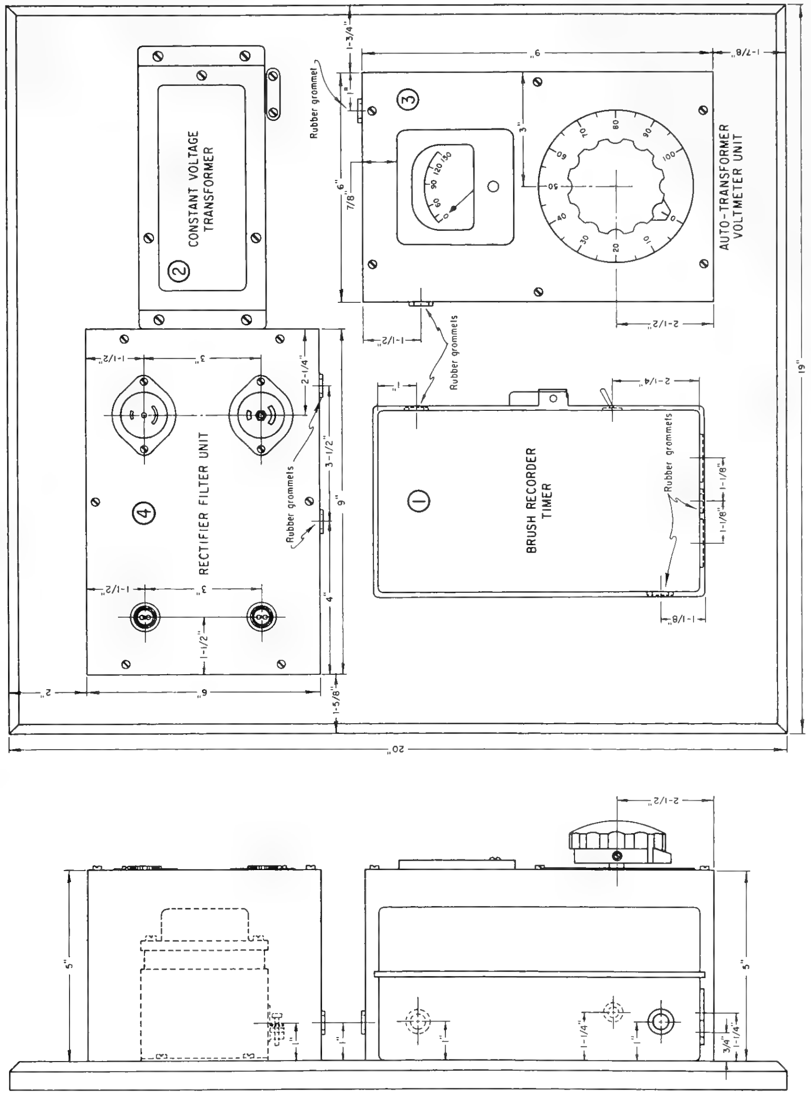


Figure 21. Panel Assembly for Parallel-Resistance Gage

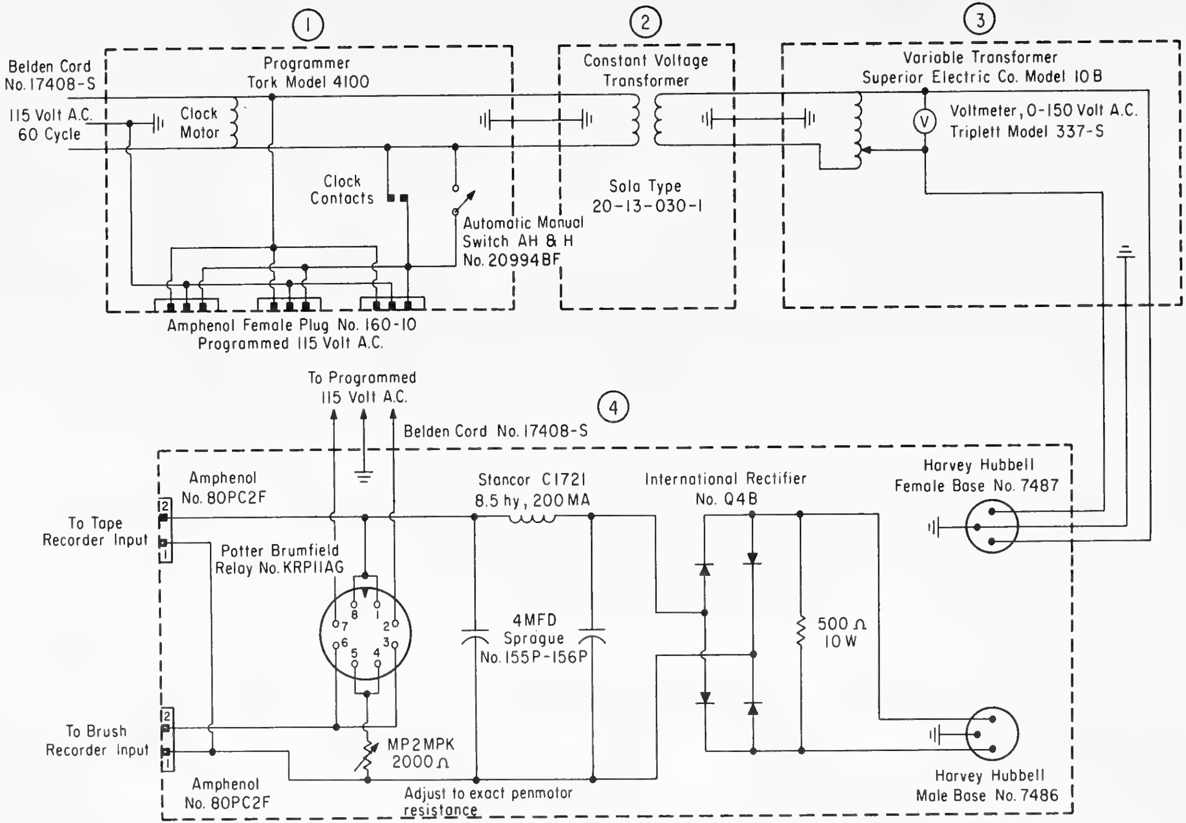


Figure 22. Wiring Diagram for Power Supply and Programmer of Parallel Step-Resistance Gage.

3. Operation of Parallel-type, Step-Resistance Gage

a. Installation

Install the metal gage holder at the operation site. The holder should be installed so that about 6 to 8 feet are below mean lower low water and 17 to 19 feet out of the water.

Provide a mounting for the transformer unit near the top of the gage mount but do not mount the transformer unit at this time.

Install the 4-conductor No. 14 AWG cable between the gage holder site and the recorder site.

Install the epoxy gage sections in the mount.

Install the voltage-control programmer unit, the strip-chart recorder, chart take-up and magnetic tape recorder (if used) at their operating site. Connect these units and the transformer unit to the gage sections as shown on Figures 23 and 24.

b. Calibration

The accuracy of the recorded wave heights depends directly on the accuracy of the calibration of the gage. There are enough differences in each wave gage and each strip-chart recorder to require that each gage be individually calibrated.

The ideal calibration would be that of raising and lowering the steel gage holder with the gage sections into the water in small increments and marking the strip-chart recorder accordingly. Usually, the lack of water depth, the manual process required, and the presence of wave action prevent such calibration.

If many gages are to be calibrated, it may be desirable to provide a water basin about 24 inches in diameter with the required depth. A wave gage holder would be a permanent part of the calibration pit. The basin should be made of concrete pipe or other nonconducting material; use of a metal wall would cause inaccurate calibration of the gage. Water with proper salinity would be required.

The procedure outlined below has been used and found satisfactory for calibration of staff-type gages. If feasible, a time of low wave action should be selected.

If possible, keep the sections to be removed from the water first in the calibration process inside the steel gage holder. This will provide a more accurate gage calibration. If the water is deep enough, place two or three of the sections in the holder in the order that they are used in the gage. The section having the lowest value of resistors is on top, and

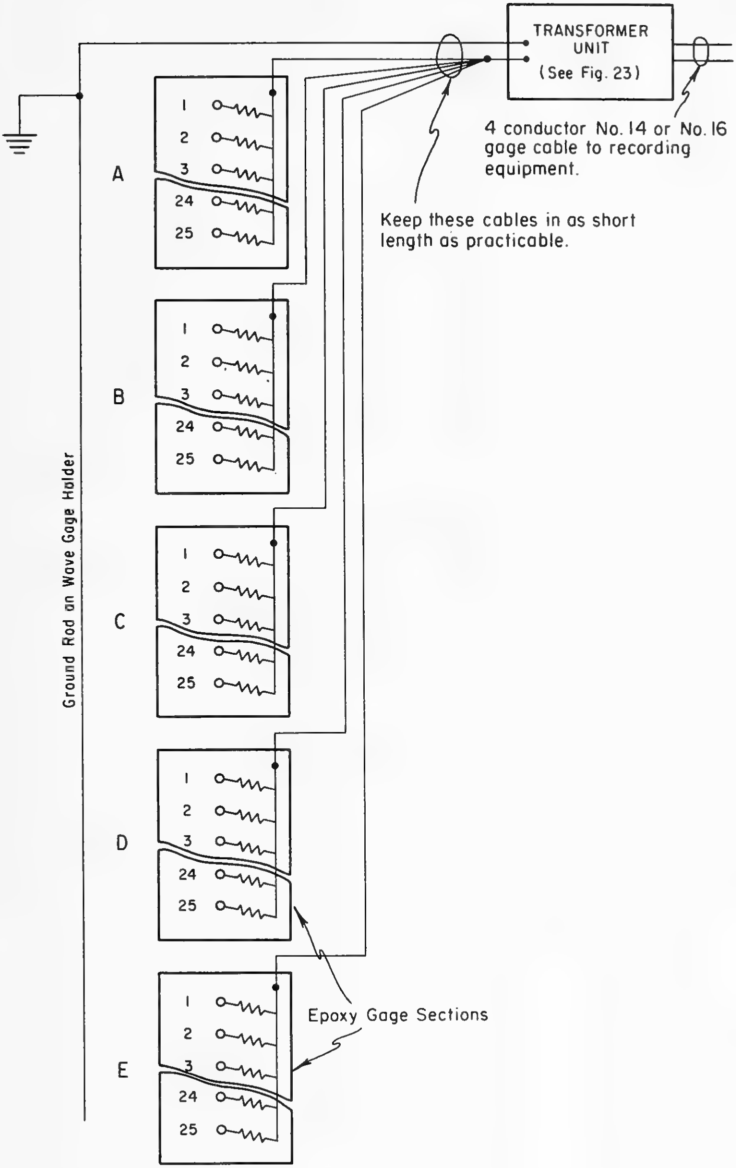


Figure 23. Connecting Diagram for Parallel Step-Resistance Gage Section

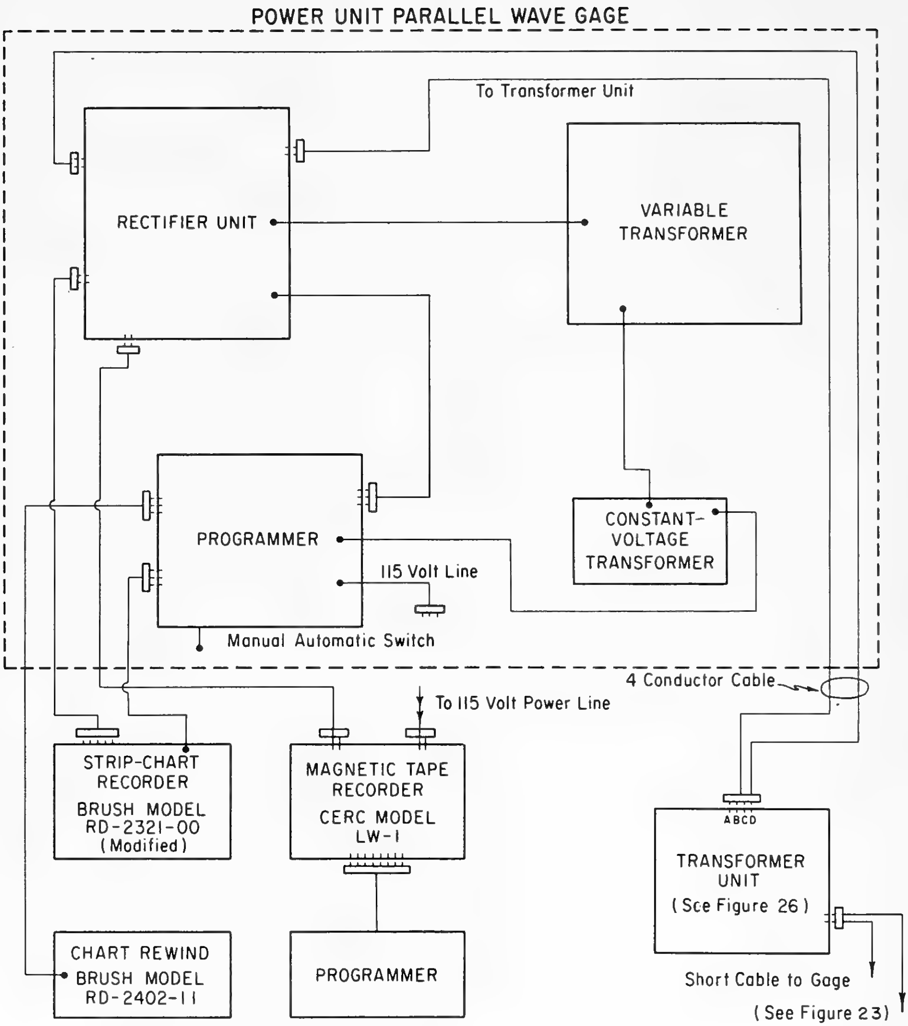


Figure 24. Hookup Diagram for Parallel-type Step-Resistance Gage.

the succeeding sections are below it. When the section having the lowest value of resistors has been removed from the holder (in the desired calibration increments), the other gage sections in the holder should be removed and a succeeding section put in the bottom; thus, all sections having the lowest resistors will be removed from inside the gage mount in succession during the calibration process.

Calibration of the gage proceeds as follows:

a) If a magnetic tape recorder is used, calibrate it with the strip-chart recorder as outlined on page 93.

b) Remove the epoxy gage sections from the gage mount.

c) Set the a.c. voltage-adjust control (autotransformer) on the voltage-control, rectifier-filter, programmer unit to its counterclockwise position.

d) Apply power to the gage system and turn on the strip-chart recorder.

e) Using the mechanical adjusting lever on the strip-chart recorder penmotor, adjust the recording pen to the left side of the recording chart.

f) Place all epoxy gage sections under water. The sections should be placed adjacent to the metal gage holder with the lead contact tips near the ground rod. The spacing between the tips and the ground rod should be nearly the same as that provided when the sections are inside the gage holder.

g) Adjust the a.c. voltage control clockwise to provide full-scale movement of the strip-chart recorder pen.

h) Repeat steps b, e, f, and g until zero and full scale are stable.

i) Remove the top epoxy gage section from the water 1 foot at a time, and mark the strip-chart recording accordingly. Continue with the remaining gage sections. This is the calibration for the wave gage. If the calibration is nonlinear, clean the lead contact tips on the gage sections, check the electrical connections of the epoxy gage cables and the connection to the ground rod, and recalibrate.

j) Mount the transformer unit near the top of the gage holder.

k) Adjust the programmer to provide the desired recording periods of the wave gage. The programmer may be set to provide a recording beginning any hour for a selected number of minutes. Hours may be skipped by proper installation of the knurled screws in the programmer dial.

l) Place the epoxy gage sections in the gage holder.

m) Gage is now in operation.

c. Maintenance

The gage sections and mount will require cleaning as dictated by local marine growth conditions.

Repainting the gage mount and the lower epoxy sections with anti-fouling paint will extend the periods between cleaning. DO NOT PAINT THE GROUND ROD AND THE LEAD TIPS IN THE EPOXY GAGE SECTIONS.

Recording charts and ink will require replacement at intervals in proportion to the recording program selected.

SECTION IV. RELAY-TYPE STEP-RESISTANCE GAGE FOR SALT AND FRESH WATER

1. Theory of Operation of a Relay-Type Step-Resistance Gage

The CERC relay-type step-resistance gage is designed for operation where water salinity is expected to vary widely. This variation may approach that of fresh water or that of sea water with little change in gage operation. This gage holds calibration longer than other staff gages.

The gage operates on the principle of water completing a circuit consisting of a power supply, a relay coil, and a switch (the switch is the water path) in series (see Figure 25 on the following page).

The gage uses 125 relays for a 25-foot gage, each relay closing when its associated water contact is submerged. Only one power supply is required to operate all the relays.

In order that the relays will operate in both fresh and salt water, it is necessary to modify the basic circuit in Figure 25 to the circuit in Figure 26.

Electrolytic action in the water path makes it necessary to use alternating current in the gage circuit. However, when an a.c. relay is used, excessive relay chatter shortens relay life. This limitation makes it necessary to select a d.c.-operated relay, and subsequent selection of suitable rectifiers and filters for converting the a.c. gage-circuit potential to d.c. for relay operation.

The basic relay circuit requires approximately 18 volts for operation in fresh water. When the same voltage is applied to the gage circuit in salt water, the voltage across the relay coil exceeds the coil voltage rating. To overcome the relay-coil overload, a 28-volt .07 ampere pilot lamp is installed to provide relay protection in salt water. In addition, this lamp will have a lower resistance value when not fully excited, thereby providing a correspondingly higher voltage to the relay coil when used in fresh water.

The relays are connected to the copper contacts on the epoxy gage sections so that when the bottom contact on the gage is submerged, relay No. 125 is first to close, and when all contacts are successively submerged, relay No. 1 will be the last to close.

The a.c. power-supply voltage to the relay circuit is adjustable by changing a jumper wire on a terminal strip on the power-supply chassis. The voltage should be adjusted to the minimum value that will provide positive relay closure at the location of the gage. For sea water, 9 to 12 volts should be adequate; for most fresh water locations, 18 to 24 volts should be adequate.

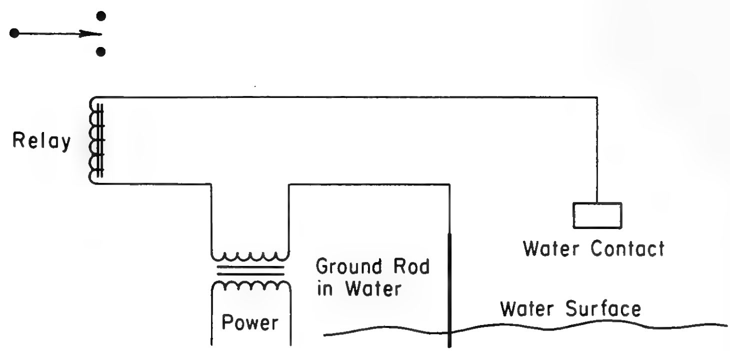


Figure 25. Simplified diagram of relay-type, step-resistance gage.

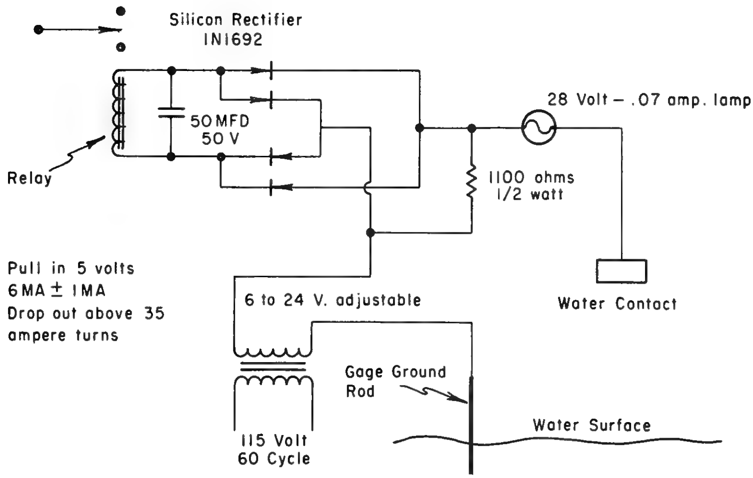


Figure 26. Modified circuit for relay-type, step-resistance gage.

Gage response (relay response) to a rising water surface is practically instantaneous. Gage response to a falling water surface is directly affected by the water salinity and cleanness of the epoxy gage sections. The epoxy gage sections should be kept as free of sea growth and dirt as local conditions will permit. Visual observations of wave action (counting the number of gage contacts from wave crest to trough) on the staff and comparison with the recorded wave record should provide evidence of proper gage operation. If local conditions permit, cleaning the epoxy gage sections and applying a coat of silicone wax to the epoxy will provide outstanding gage response. *(Do not coat the copper contacts.)*

In addition to the relay-operating circuit, the gage contains the step-resistance recorder circuit which provides the signal to the recorder as dictated by the number of relays activated by the water level.

The circuit in Figure 27 shows that when all relays are in the unenergized condition (no gage contacts submerged), the step-resistance circuit is open and no voltage is available to the recorder input. When the bottom gage-contact is submerged and relay No. 125 operates, all resistors in the step-resistance network are in series with the d.c. power and recorder input. As each gage contact is submerged and the relays are operated, the resistors are short-circuited. This provides a higher voltage to the recorder as each relay closes (voltage to recorder is higher as the gage is submerged). Thus, the recorder will follow the change in water submergence of the wave staff.

2. Fabrication of a Relay-Operated Step-Resistance Gage

Fabricate the required number of 5-foot gage sections as required for the wave station. Table VII is a parts list for a relay-operated gage. Fabrication details of the sections are shown in Figure 28. Resistor values and cable color-code are in Table VIII. Cable lengths for the sections should be selected for the shortest length practicable to reach the location of the relay cabinet. Cost of the 25-conductor cable used in the fabrication of the epoxy sections is about $0.50 per foot, thus, a five-section gage will have a cable cost of $2.50 per foot between the gage mount and the relay cabinet.

Fabricate the relay panels and relay power supply according to Figures 29 and 30, and wire them as shown in Figures 31 and 32. Mount these units in the relay cabinet as shown in Figure 33.

Modify the strip-chart recorder paper speed (if desired) as outlined on pages

Install three female 115-volt receptacles, one toggle switch and a line cord in Tork Timer Model 4100 as outlined on Figure 10.

Fabricate a metal gage holder of proper length as shown on Figure 14. Fabricate gage-holder mounting brackets as local installation requirements

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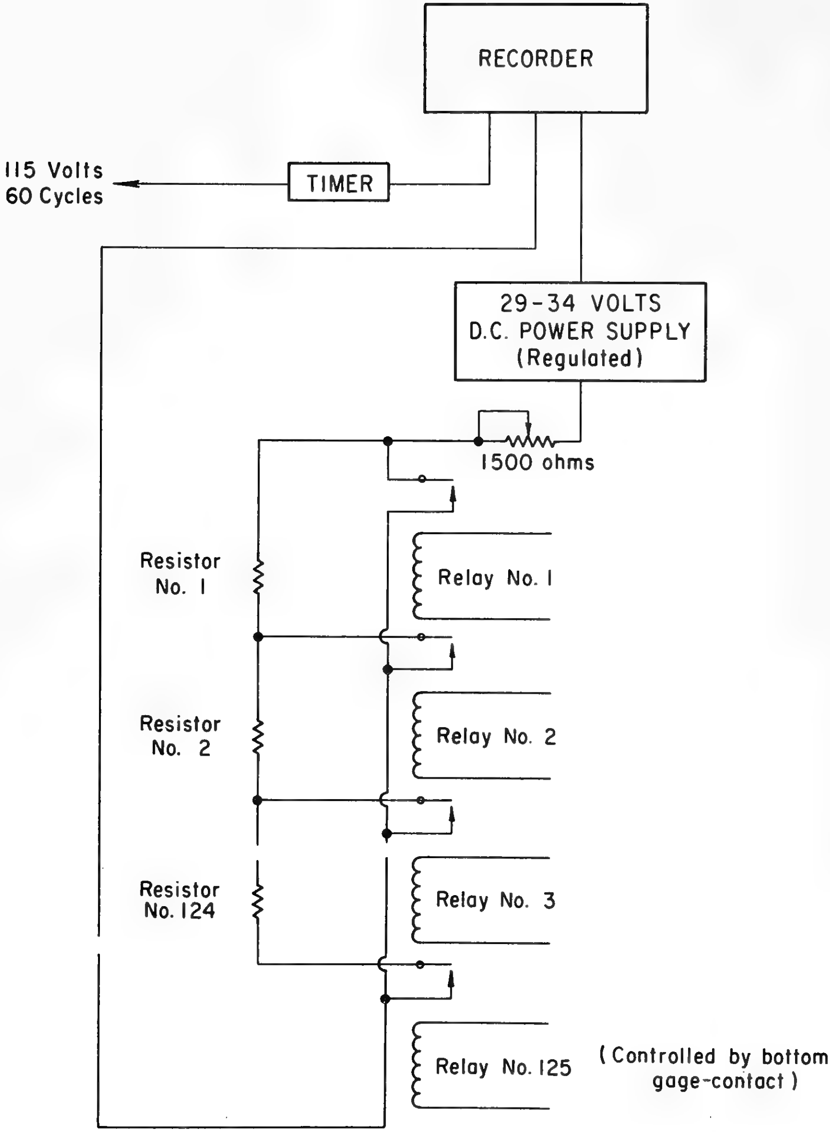


Figure 27. Simplified Diagram for Relay-Gage

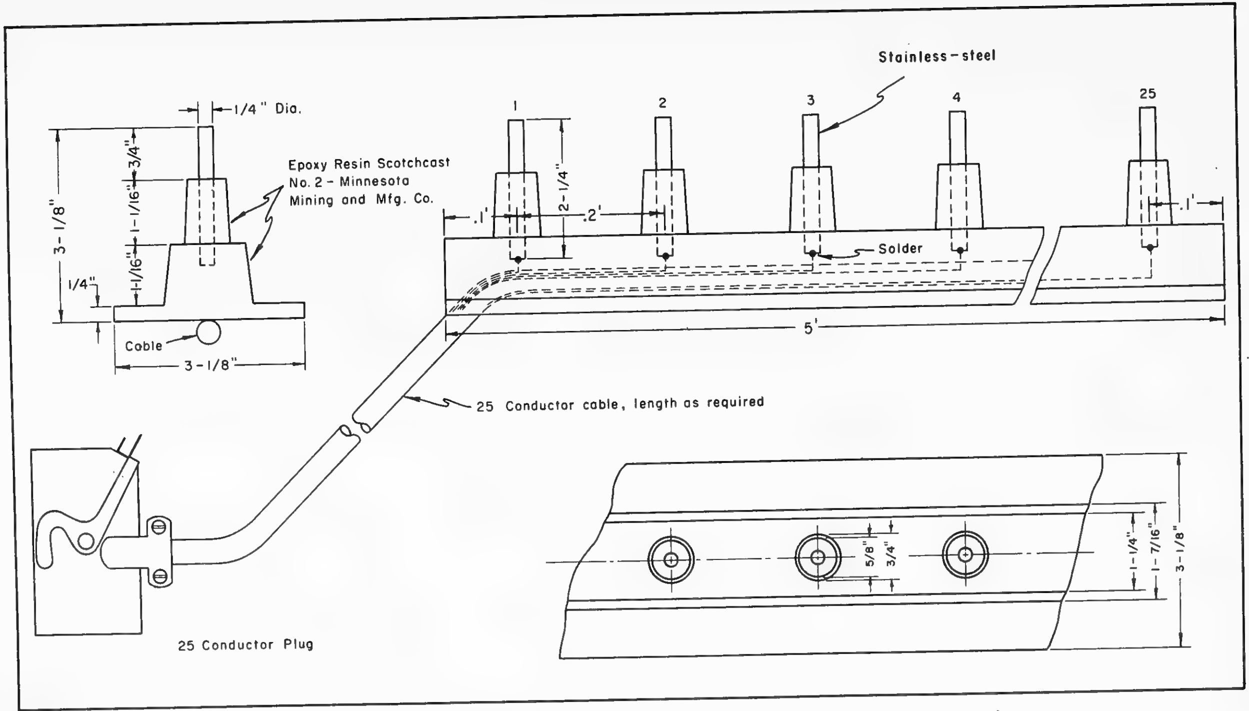


Figure 28. Relay operated step-resistance wave gage for use in fresh or salt water.

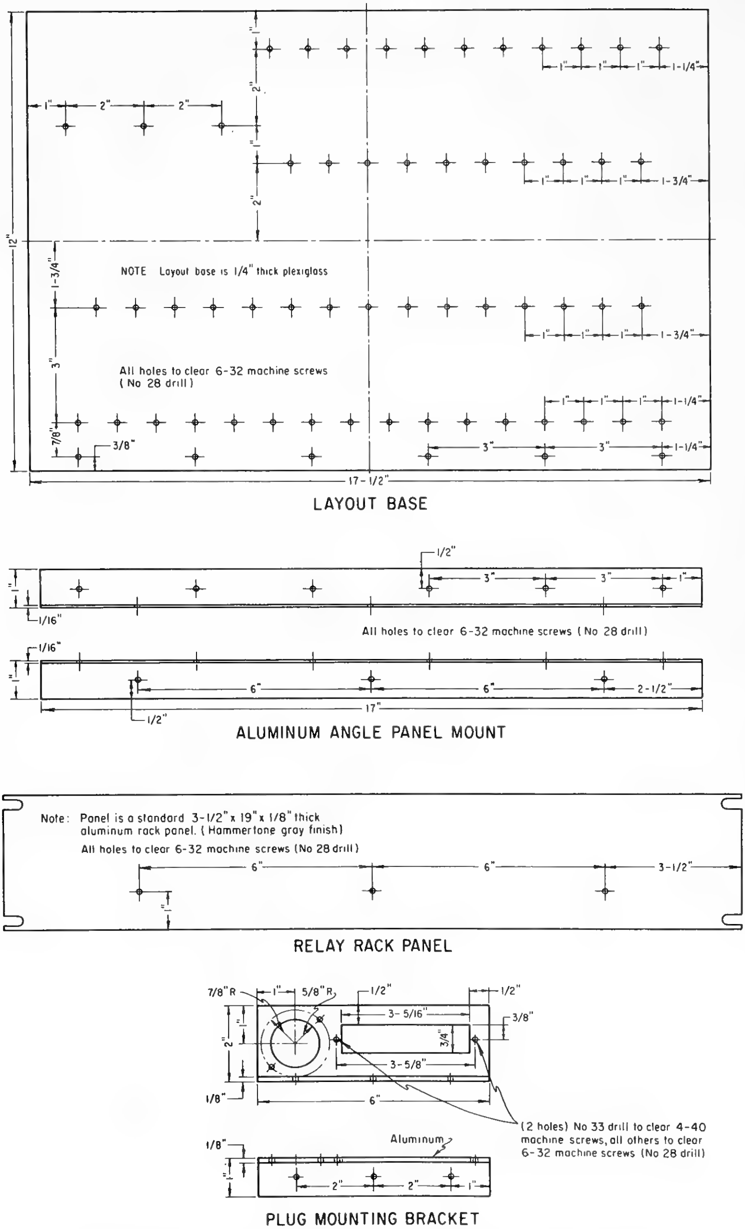


Figure 29. Relay-panel layout for relay-type gage.

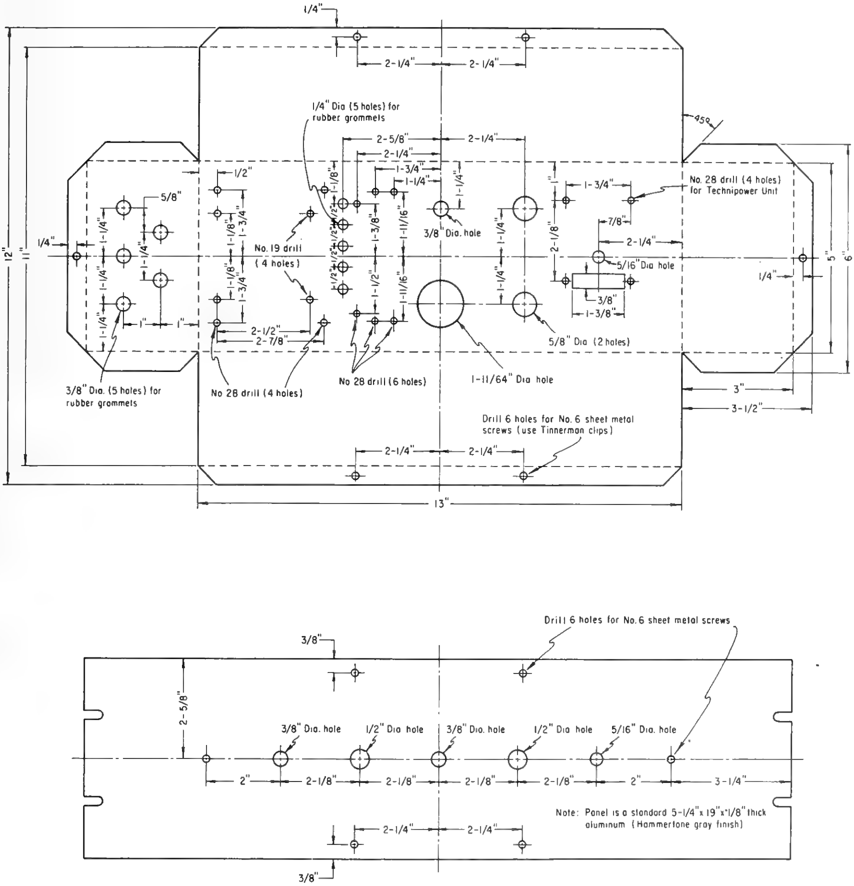


Figure 30. Front panel and chassis drilling for relay-type gage

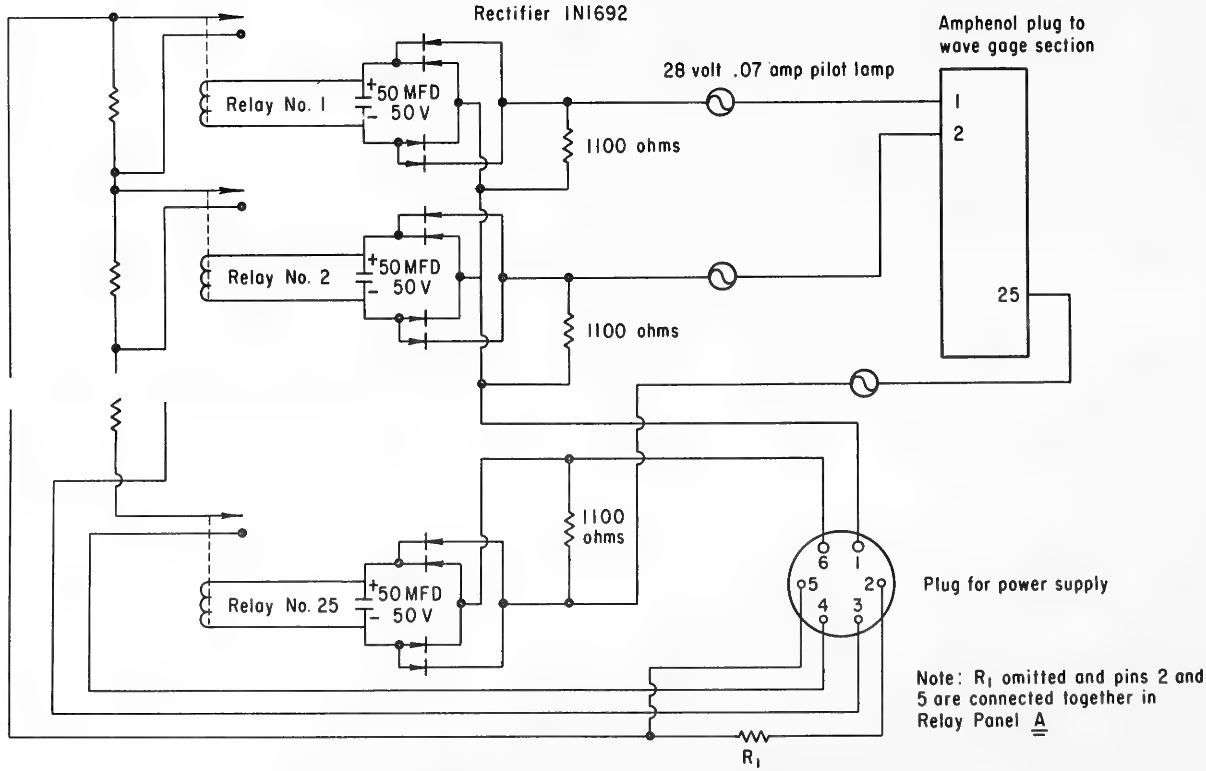


Figure 31. Relay Panel - A, B, C, D, E.

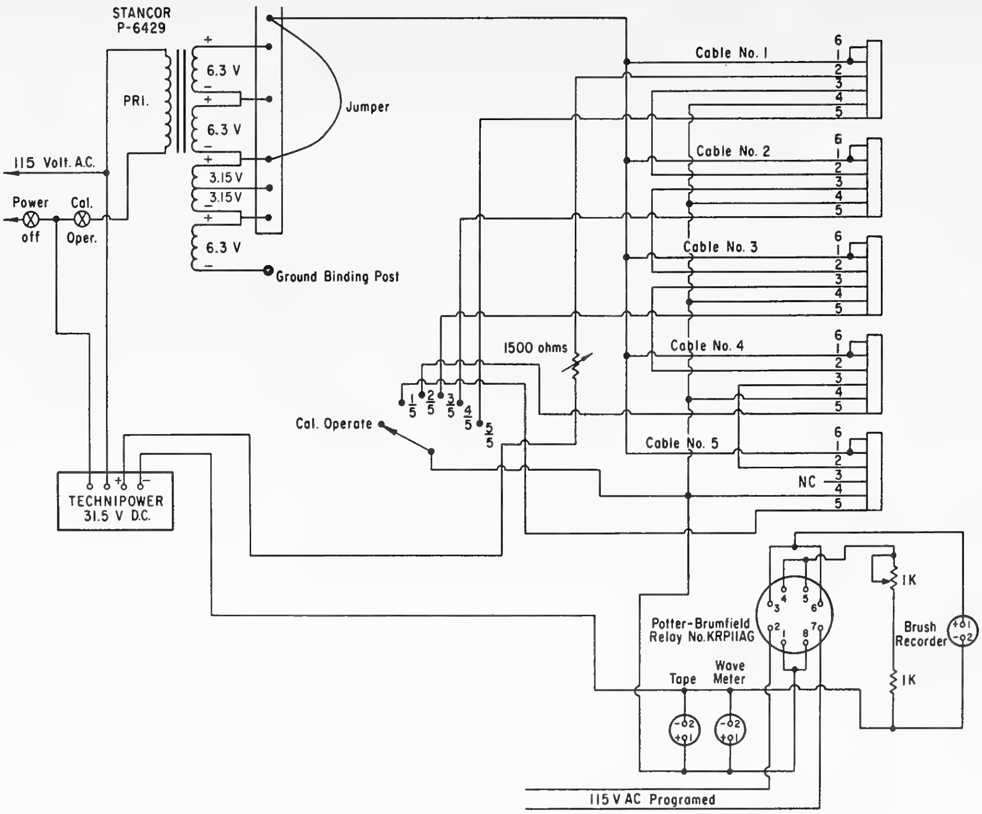


Figure 32. Power Supply for relay staff gage.

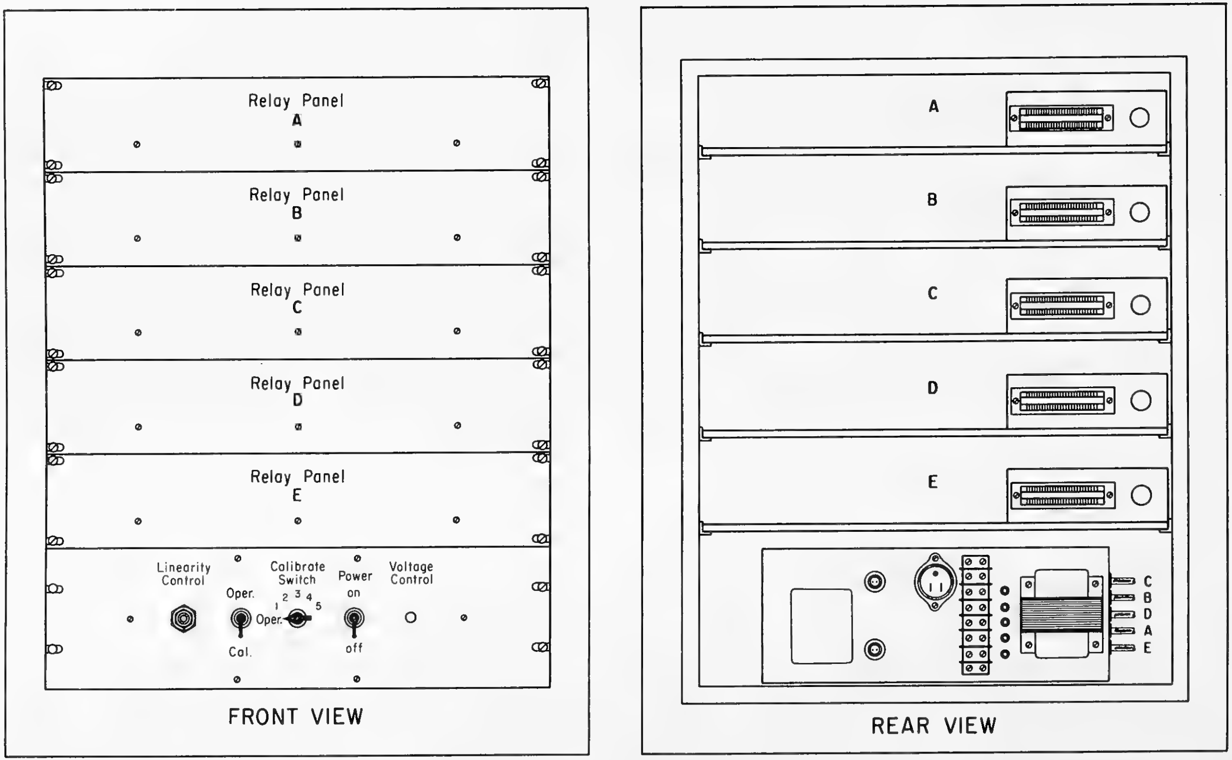


Figure 33. Cabinet Assembly for Relay-type, step-resistance gage.

TABLE VII

COMPONENTS FOR FIVE-SECTION 25-FOOT RELAY STAFF GAGE

1.	Relay assembly consisting of Wabash magnetic coil No. L4988, or equal and Hamlin DRG-1 contact relay, or equal. Relay contact material is to be silver relay contacts to close at 3.85 ± 0.15 volts and 5.8 ± 0.2 milliamperes. Relay contacts to open at 3.3 ± 0.2 milliamperes.	125 ea.
2.	Machine screws steel nickel plated binder head, 6/32 x 1/2" long.	500 ea.
3.	Hookup wire (Alpha #1500 #24 Standard (any color)	500 ft.
4.	Nuts, steel nickel plated 6/32 x 1/4"	500 ea.
5.	Lockwashers, internal teeth #6	500 ea.
6.	Aluminum angle, 1" x 1" x 1/16" thick	10 ft.
7.	Aluminum angle, 1" x 2" x 1/8" thick	5 ft.
8.	Cable, 25-conductor - Marsh and Marine, Houston, Texas Type XS CG 13R.	As required.
9.	Scotchcast Resin #2, Minnesota Mining & Mfg. Co.	42 lbs.
10.	Stainless Steel #316, round rod 1/4" O.D.	20 lbs.
11.	Plexiglas sheet 1/4" thick, 36 x 36	1 sheet
12.	Precision Resistors, wire wound 1%, Type TX-2212, manufactured by Precision Resistor Company, Hillside, N.J. (See Table V)	124 ea.
13.	Rotary Switch Centralab #PA-2000 1 pole, 2-12 position shorting type.	1 ea.
14.	Capacitor, Cornell-Dubilier ECSP 50-50	125 ea.
15.	Semiconductor rectifier, GE type 1N1692	500 ea.
16.	Resistor 1,100 Ohm 1/2 watt 5% IRC GBT 1/2	135 ea.
17.	Amphenol plug #26-4301-32 P	5 ea.
18.	Amphenol receptacle #26-4401-32S	5 ea.

19.	Pilot Lamp #1829-28 V.O. 07 amp.	135 ea.
20.	Pilot Lamp Socket - Dialco #7-87	125 ea.
21.	Aluminum chassis Bud #AC-422, 5" x 13" x 3"	1 ea.
22.	Socket, 6 prong, Amphenol #78S6, with amphenol #3-24 cable clamp	5 ea.
23.	Plug, Amphenol 86-RCP6	5 ea.
24.	Switch, SPST-12 Amps-AH & H #80607	2 ea.
25.	Panel aluminum, 3 1/2" H x 19" W, Bud #PA-1103-HG, Hammertone Gray.	5 ea.
26.	Panel aluminum, 5 1/4" H x 19" W, Bud #PA-1103-HG, Hammertone Gray.	1 ea.
27.	Cabinet - Panel 26 1/4" H x 19" W, Bud CR-1744 HG Hammertone Gray.	1 ea.
28.	Relay DPDT 115 v. 60 cycles Potter Brumfield KRP11AG	2 ea.
29.	Timer Tork Hourmaster #4100	1 ea.
30.	Cable, 2-conductor stranded, AWG #18 Type SV, Belden 8452	8 ft.
31.	Cable, 5-conductor stranded, 3-AWG 20, 2-AWG 18, Belden 8455	35 ft.
32.	Binding post, G.C. Electrocraft 33-270B	1 ea.
33.	Transformer, Stancor #P6429	1 ea.
24.	Solder, 18 S.W.G. 60% tin/40% lead	1 lb.
35.	Clip #UMC-10 Sprague Products Co.	130 ea.
36.	Wire, copper, solid-tinned AWG #18	100 ft.
37.	Potentiometer, 1,500 Ohms Mallory M1.5MPK	1 ea.
38.	Terminal Block, H. H. Smith #602-5, General Purpose Bakelite.	1 ea.

39.	Shaft lock H. H. Smith #181	3 ea.
40.	Female Chassis receptacle amphenol #80-PC2F	2 ea.
41.	Male cable plug amphenol #80-MC2M	2 ea.
42.	Cord Belden #17460-S	2 ea.
43.	Plug amphenol #86CP8 with #324 cable clamp	1 ea.
44.	d.c. Power supply output volts 29.2 - 32.7, output current 0.050 amps accuracy ± 0.05% Model M-31.5-050A, manufactured by Technipower, Inc. 18 Marshall Street, South Norwalk, Conn., Rep. Whitcomb Associates, 730 Deepdene Road, Baltimore, Md.	1 ea.
45.	Plug amphenol #160-5	1 ea.
46.	Potentiometer, 2,000 Ohms, Mallory M2MPK	1 ea.
47.	Strip-Chart Recorder Brush Model No. RD-2321-00. Order with following modifications: Single channel operation and 50 mm chart width. Old style Penmotor #BL902 and Long pen #BL 921.	
48.	Chart take up drive Brush No. RA 2402-10	1 ea.

NOTE: Less steel "H" Beam for holding epoxy gage sections.

TABLE VIII

RESISTOR VALUES IN OHMS FOR 125-POINT RELAY GAGE

13.5	21.1	37.7	85.3	348
13.7	21.5	38.7	88.0	379
13.9	22.0	39.8	92.7	413
14.2	22.4	40.9	96.7	452
14.4	22.9	42.1	101.	498
14.6	23.4	43.3	106.	550
14.9	23.9	44.5	110.	611
15.1	24.4	45.9	116.	683
15.4	25.0	47.3	121.	768
15.7	25.5	48.7	127.	871
15.9	26.1	50.2	134.	995
16.2	26.7	51.8	141.	1149
16.5	27.3	53.5	149.	1340
16.8	27.9	55.3	157.	1584
17.1	28.6	57.1	166.	1900
17.4	29.3	59.0	176.	2323
17.8	30.0	61.1	186.	2901
18.1	30.7	63.2	198.	3733
18.4	31.5	65.5	211.	4977
18.8	32.2	67.9	225.	5968
19.1	33.1	70.4	240.	10453
19.5	33.9	73.0	257.	17423
19.9	34.8	75.8	276.	34817
20.3	35.7	78.8	298.	104500
20.7	36.6	82.0	322.	

CABLE-COLOR CODE FOR RELAY GAGES

1 Brown
2 Red

3 Brown
4 Clear

5 Red
6 Orange

7 Red
8 Yellow

9 Red
10 Green

11 Red
12 Blue

13 Red
14 White

15 Red
16 Clear

17 Orange
18 Clear

19 Yellow
20 Clear

21 Green
22 Clear

23 Blue
24 Clear

25 White
26 Clear (spare conductor)

dictate. Brackets should be designed with adequate strength to support the gage holder during severe wave action. Figure 13 shows a type bracket that has been used successfully to support the gage holder on a vertical piling. Paint the gage holder and mounting brackets with two coats primer and three coats of a good grade commercial anti-fouling paint. Government agencies may obtain these from General Services Administration Stock No. GS8010-550-8305 and GSA Stock No. GS8010-290-6651, respectively. Paint the underwater and waterline epoxy gage sections with three coats of anti-fouling paint. DO NOT PAINT COPPER SENSING TIPS.

3. Operation of Relay Type Step-Resistance Gage

a. Installation

Install the gage holder at the operating site. The holder should be installed so that about 6 to 8 feet are below mean lower low water and 17 to 19 feet out of the water. Install ground rod in holder. DO NOT PAINT GROUND ROD.

Place epoxy gage sections in gage holder.

Install relay cabinet, strip-chart recorder, chart rewind, programmer and magnetic tape recorder (if used) in operating location.

Connect all units of the system as shown on Figure 34.

Adjust tape recorder (if used) and strip-chart recorder as outlined in Section VII, paragraph 3.

b. Calibration

Calibrate the gage as follows:

a) Apply power to the relay cabinet. Adjust the d.c. voltage from the regulated d.c. power module to 30.0 volts. Turn on the strip-chart recorder, using the toggle switches located on the programmer and rear of recorder.

b) Place the toggle switch on the relay cabinet marked "calibrate-operate" to the "calibrate" position.

c) Place the rotary switch on the relay cabinet to the "operate" position.

d) Adjust the strip-chart recorder pen to the left side of the chart paper using the lever on the side of the recorder penmotor.

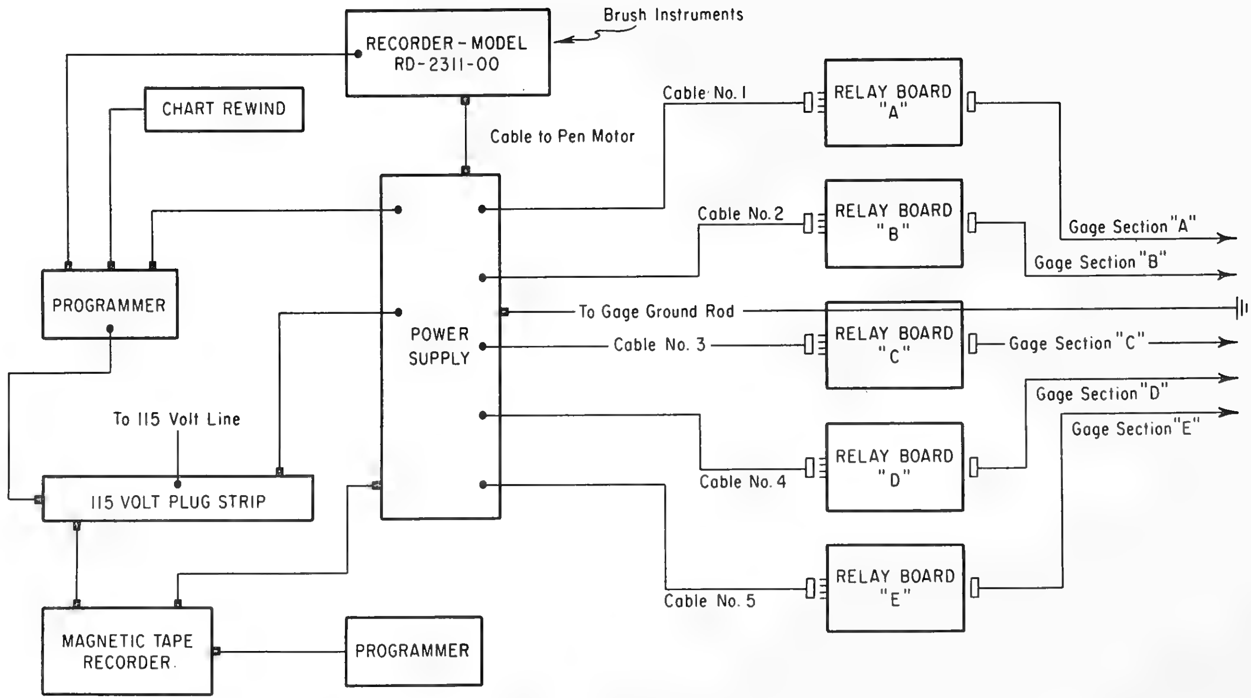


Figure 34. Block Diagram for Relay Staff Gage.

e) Place the rotary switch on the relay cabinet to position 5 (full-scale setting).

f) Adjust the linearity control on the front panel to the relay cabinet to provide full-scale pen movement on the strip-chart recorder.

g) Move the rotary switch to its intermediate calibrate positions and mark strip-chart recorder accordingly.

h) Check strip-chart recorder for linearity. If recording is not linear, adjust d.c. voltage of the regulated power module either up or down and repeat steps e, f, g, and h until linearity is obtained.

i) Place rotary switch in "operate" position.

j) Place the toggle switch marked "calibrate-operate" to the "operate" position.

k) Raise or lower the epoxy gage sections in the water, and observe the strip-chart recording for a corresponding indication.

A relay that is stuck closed will cause the recorder pen to remain at an up-scale position when all gage sections are removed from the water. A relay that does not close will be indicated by a jump in the recorder pen as the gage sections are lowered into the water. The terminal strip on the rear of the power-supply unit allows for adjustment of the voltage applied to the relay circuit. Salt-water locations require 9 to 12 volts for normal operations. Set voltage to the lowest value that will provide positive relay action and best relay fallout when the gage sections are raised and lowered in the mount. A d.c. voltmeter may be used to measure the d.c. voltage across a relay coil that is in a closed position; this voltage should be about 5.5 to 6.5 volts. Greater relay voltage will cause the relays to remain closed when the gage sections are saturated with water, but with the gage contact out of water. This is due to conductivity of water film on the gage section. Excessive voltage will cause capacitor failure in the relay circuit.

l) Adjust programmer to time recordings from the gage as desired. The programmer will provide a recording at the beginning of each hour for the selected number of

minutes. Hourly recordings may be deleted for any period by removing the knurled screws from the programmer dial.

m) Gage is now in operation.

c. Maintenance

Recorder chart and ink must be replaced in accordance with the recording program established.

The epoxy gage sections, gage holder, and brackets will require periodic cleaning to remove sea growth caused by local conditions. Repainting of the gage holder and gage sections with anti-fouling paint will extend the periods of operation between cleaning, and retard marine growth. DO NOT PAINT THE GROUND ROD OR THE METAL GAGE TIPS.

Recorders should be serviced as outlined in the manufacturer's manuals.

Periodic checking of the gage calibration is desirable.

Section V. PRESSURE-SENSITIVE GAGE

1. Theory of Operation of Pressure-Sensitive Gage

The pressure-sensitive wave gage operates on the principle that when a wave crest passes a given point there will be an increase in water depth, and with an increase in the height of the water column there will be an increase in the pressure at the bottom of the column.

While a wave crest is not exactly equivalent to closed water column, the change in water level related to a wave crest or trough will cause a pressure change at the ocean bottom. If a pressure-sensitive device is placed near the ocean bottom, it will sense the pressure change caused by the wave.

The signal from the pressure-sensitive device may be carried to a shore location over an electrical cable, and recorded on a paper-strip chart or magnetic tape recorder. Since the signal at the recorder is produced by the wave crest and trough, it is directly related to the wave.

The pressure change produced by a wave train of constant amplitude and constant period will decrease as the pressure sensor is placed deeper and deeper in the water. If the wave period is made shorter, the pressure from the same wave height will also be reduced at a constant water depth. Ratios for conditions of pressure, depth, wave height and wave period have been established, and may be used to correct the recordings from a pressure-sensitive wave gage to provide a usable measurement of wave conditions.

Ripples and small sharp surface changes will be filtered out of the wave record due to the pressure-period attenuation outlined above. This filtering will influence the wave spectra analysis so that there will be apparent differences when comparing spectra data taken at the same time and location with both pressure and staff gages.

The change in tide at locations where pressure wave gages are used must be known. The increased water depths due to tide is, in effect, an increase in water depth, which must be used in correcting the wave record.

For these reasons a pressure-sensitive gage is not an ideal device for gathering true data on waves. This gage is recommended only for those locations where the installation of a step-resistant staff-type gage is impracticable due to the cost of a mounting structure or where a mounting structure would cause a navigational hazard.

The CERC-designed pressure-sensitive gage uses a Sylphon bellows that changes its length with an increase in pressure. The bellows movement is coupled to the core of a linear differential transformer by a permanent magnetic, steel ball, universal joint.

Movement of the core in the differential transformer produces a linear d.c. output voltage from the unit. This signal, representing the wave conditions, is amplified and applied to a strip-chart recorder.

2. Fabrication of a Pressure-Sensitive Gage

Fabricate the pressure-sensitive underwater unit as outlined on Figure 35. Table IX is a parts list for this gage. When soldering the end caps to the bellows, ensure that a watertight seal is provided and also prevent any solder from entering the corrugations of the bellows. The end for the bellows which is drilled for the magnet should be soldered to the bellows first. The magnet should then be inserted using an epoxy cement to ensure that it remains in place. The threaded end for the bellows is then assembled (soldered) using the minimum heat required for soldering. Too much heat could lower the efficiency of the magnet. It is recommended that edges of the bellows and the end caps be tinned prior to soldering into an assembly. It is also recommended that liquid stainless steel flux and solid wire solder, 60 percent tin and 40 percent lead, be used.

When assembling the bellows unit to the main gage housing, use of Permatex No. 2 on threaded surfaces is recommended. The Permatex should be used sparingly, applying only a thin coat on both the male and female threaded parts. Prior to closing the space between the bellows and gage housing, remove any excess Permatex from inside the "O" ring; align the brass ring, which incloses the "O" ring, with the outside gage housing and tighten the housing firmly. Do not use the bellows as a purchase grip to tighten the assembly; vise grip pliers and a bench vise are recommended.

The bellows should be assembled to the gage case, and the entire case and bellows tested for leaks prior to further assembly. This can be done by attaching a fitting to the cable end of the gage housing, filling the inside with air to about 30 pounds per square inch gage, and testing under water for bubbles. During this test, the bellows snould be blocked mechanically to prevent stress beyond its ratings. Blocking may be accomplished by using large plastic washers with small holes in their edges for accepting wire to hold the bellows in a blocked position. The washer used on the threaded end of the bellows will require a slot with an opening in order to place it above the bellows cap as shown in Figure 36.

After testing the bellows and housing assembly, a short length of gage cable is fitted into the end of the gage housing and sealed with epoxy resin. Splicing the cable ends to a very fine flexible wire in the epoxy seal will aid later assembly of the transducer. Clean, but do not oil, the sliding core in the Sanborn linear differential transformer. Clean the core and center hole thoroughly. If the core does not slide freely in the transformer, return the transformer and core to the manufacturer for repair or replacement. Any binding of the core will cause it to separate the steel ball from the magnet and render the gage useless. The steel ball and magnet provide a backlash-free universal joint that allows free movement of the core within the transformer. The core

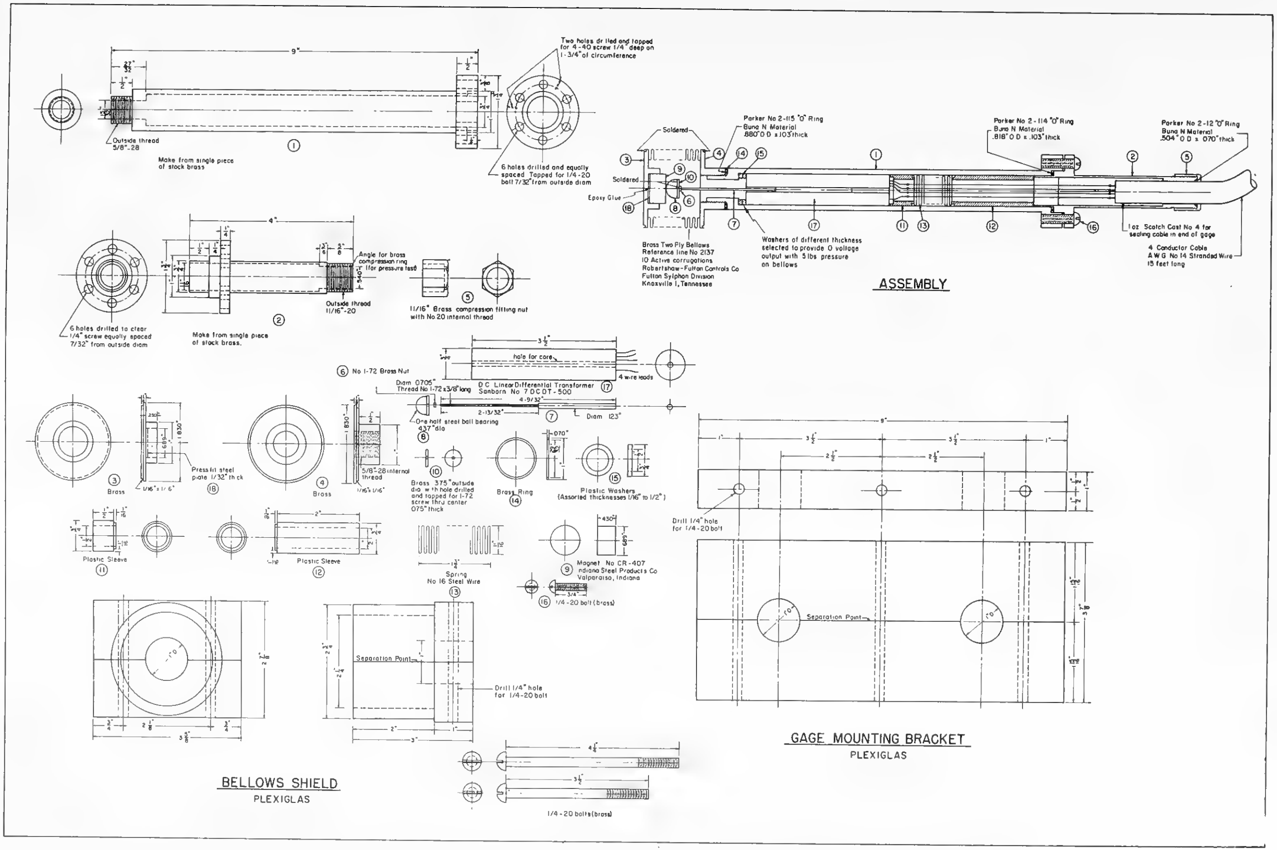


Figure 35. Parts and Assembly Drawing of Pressure-Sensitive Gage.

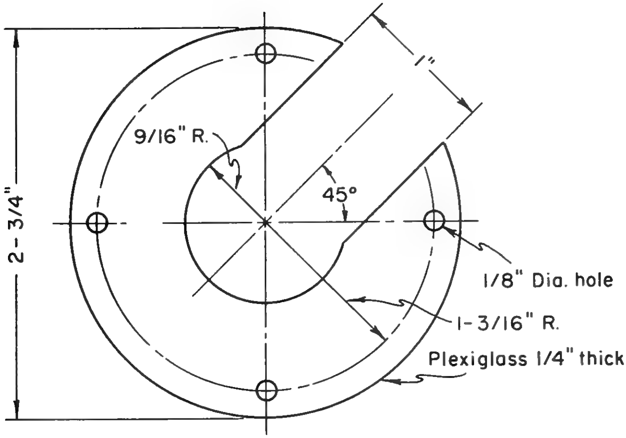
TABLE IX

LIST OF COMPONENTS FOR PRESSURE-SENSITIVE GAGE, MODEL BE-2

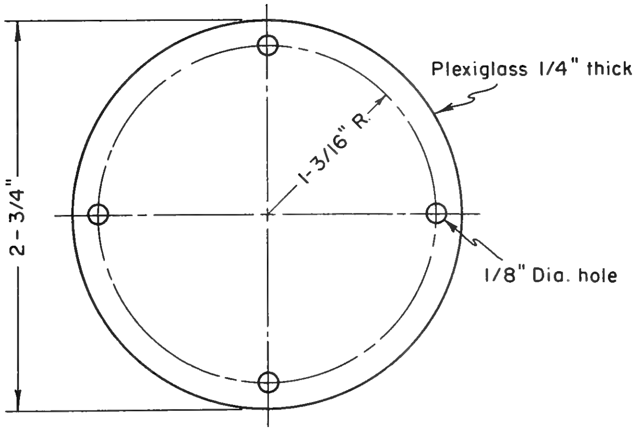
1.	Brass parts and magnet as shown on drawing, "Pressure Wave Gage Model BE-2.	1 set
2.	Bellows, 2-ply brass, 10 active corrugations, reference line No. 2137, Robertshaw-Fulton Controls Co., Fulton Sylphon Division, Knoxville, Tennessee.	1 ea.
3.	Transducer, d.c. differential transformer displacement, DCDT, Model 7DCDT-500, Sanborn Company, Transducer Division, Waltham, Massachusetts.	1 ea.
4.	Amplifier, Transistorized operational, Model TR-1 with mating amphenol connector suitable for chassis mounting, Boonshaft & Fuchs, Inc., Hatboro Industrial Park, Hatboro, Pennsylvania.	1 ea.
5.	Power supply, dual-output regulated, 60 volts d.c. Model 60B10D-60B10D, Acopian Technical Company, Easton, Pennsylvania.	1 ea.
6.	Power supply, regulated-output 6.0 volts d.c., 0.375 amperes d.c. Model M-6.0-0.375A, Technipower, Inc., South Norwalk, Connecticut.	1 ea.
7.	Socket, Amphenol, 11 prong #78S11	1 ea.
8.	Chassis, aluminum 6" x 17" x 3", Bud AC-433	1 ea.
9.	Splicing kit, Scotchcast #82-A1	1 ea.
10.	Cord Set Belden 17408-SJ	2 ea.
11.	Connector, male cable plug, amphenol type #80-MC2M	2 ea.
12.	Connector, female receptacle, amphenol type 80PC2F	2 ea.
13.	Socket, octal, amphenol #78RS8	1 ea.
14.	Capacitor, Mallory, No. HC10100, 10,000 MFD 10VSP	1 ea.
15.	Plug, 3-prong, male with shell, amphenol #160-5	1 ea.
16.	Cord Set, Belden 17460-S	1 ea.
17.	Switch, toggle SPST, Arrow Hart & Hegeman #20994-BF	3 ea.
18.	Socket, 3-prong female chassis mounting type amphenol #160-10	3 ea.

TABLE IX (continued)

19.	Time switch, Tork #4100	1 ea.
20.	Potentiometer, 10-turn, 200 K ohms, IRC type HD-150	1 ea.
21.	"Revodex" dial, IRC type RD-462	1 ea.
22.	Relay DPDT, 115-volt, 60 cycles, Potter Brumfield KRG 11AT	1 ea.
23.	Binding Post, Superior type DF 30 GNC (Green)	1 ea.
24.	Binding Post, Superior type DF 30 WTC (White)	1 ea.
25.	Binding Post, Superior type DF 30 BC (Black)	1 ea.
26.	Binding Post, Superior type DF 30 RC (Red)	1 ea.
27.	Capacitor, .047 MFD, 200 WVDC, Cornell-Dubilier Type WMF 2S47	1 ea.
28.	Potentiometer 2,000 Ohms Mallory #M2MPK	1 ea.
29.	Nameplate, Brass	1 ea.
30.	Solder, 18 S.W.G. 60% tin/40% lead	1 lb.
31.	Resistor, 2,700 Ohms, wire wound, 1 watt, 5% tolerance	1 ea.
32.	Material for Concrete mounting block	
33.	Strip-chart recorder, Brush #2321-00. Order with following modifications: single channel operation and 50 mm chart width. Old style penmotor #BL 902 and long pen BL 921.	1 ea.
34.	Chart rewind Brush #RA-2402-10	1 ea.



TOP WASHER



BOTTOM WASHER

Figure 36. Washers for blocking bellows of pressure gage.

assembly should be placed in the linear differential transformer and placed in the gage barrel. Plastic washers must be placed between the transformer and the bottom of the barrel. These washers must be of varying thicknesses. The electrical output of the transformer should be zero or slightly negative when the transformer is resting on the washers in the gage barrel.

Connect the differential transformer to a 6-volt d.c. source and measure the output with a high-impedence voltmeter set on a low range - about 3 volts. With the steel ball in contact with the magnet in the bellows chamber, with the bellows in free air (no pressure), and the transformer in firm contact with the plastic washers, the voltmeter should read 0 volts, or slightly negative. Pressing the bellows with the fingers should show an upscale (positive) movement of the voltmeter. If the zero or slightly negative output voltage is not obtained on first trial, then the transformer and core assembly must be removed from the gage barrel and plastic washers of a different thickness tried until the correct reading is obtained. After the correct washers are selected, put together the spring assembly and "0" ring, and solder the transformer leads to the leads in the epoxy sealed cable-end of the gage housing. Fasten the cable portion of the gage housing to the gage barrel, using 6 No. 10-32 screws. These screws should be tightened a little at a time to ensure equal pressure on all sides of the "0" ring seal.

Fabricate the amplifier, power-supply unit as shown in Figure 37; wire the unit according to Figure 38.

Construct the programmer by installing three 115-volt receptables, toggle switch and line cord on the timer as shown on Figure 10.

Change the chart speed on the strip-chart recorder (if desired) as outlined in Section VIII.

Fabricate a signal cable for the strip-chart recorder of the desired length using 2-conductor No. 18 AWG cable and connectors as shown on Figure 11.

Fabricate a suitable underwater mount for the pressure unit. This mount should be high enough to keep the gage free of the ocean bottom; it should be large enough and heavy enough to remain in an upright position during periods of heavy wave conditions. To prevent metal erosion caused by galvanic action, dissimilar metals should not be used in contact in sea water. The brass pressure-unit must be mounted in plastic insulating brackets to prevent metal erosion by galvanic action. Lifting eyes should be provided to lower the mount to the ocean floor and for attaching a marker buoy (if required). A simple concrete mount has been used for the gage in some locations (Figure 39). If a marker buoy is used, the gage should be protected from the sagging and twisting of the buoy cable.

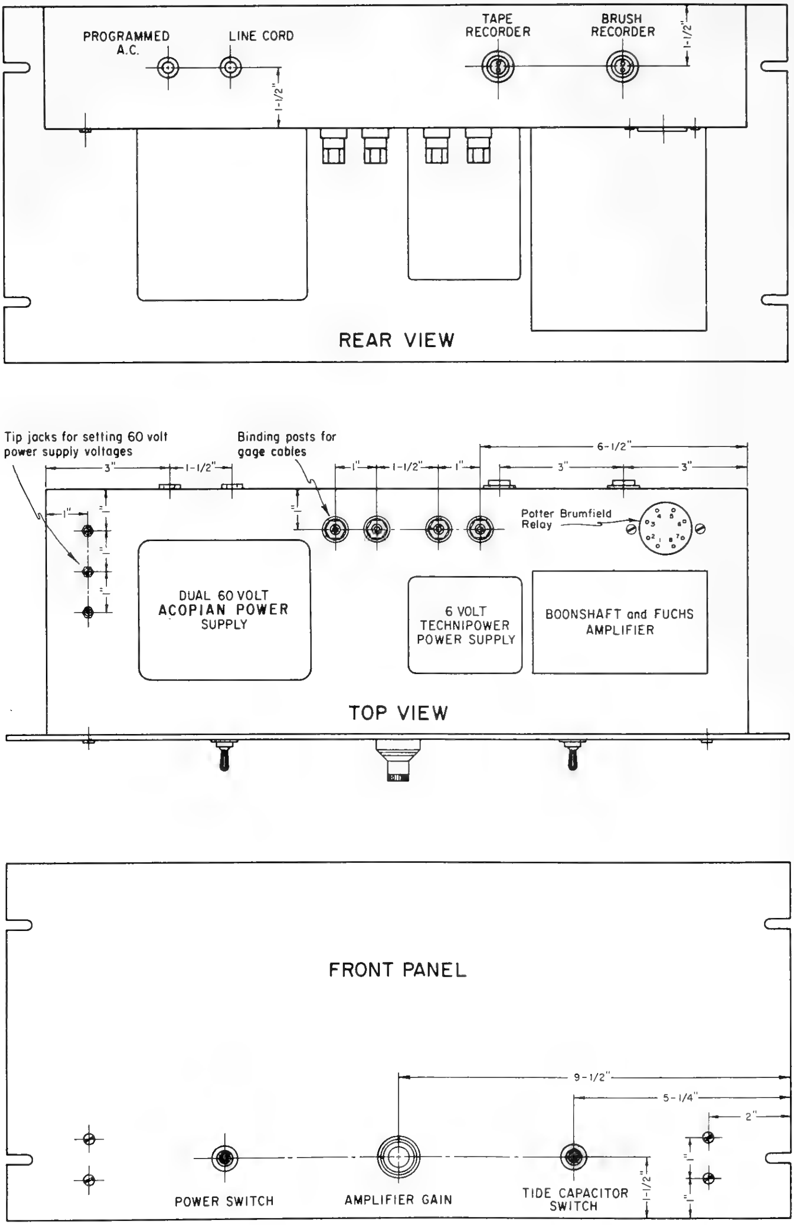


Figure 37. Power Supply Unit for amplifier of pressure-sensitive gage.

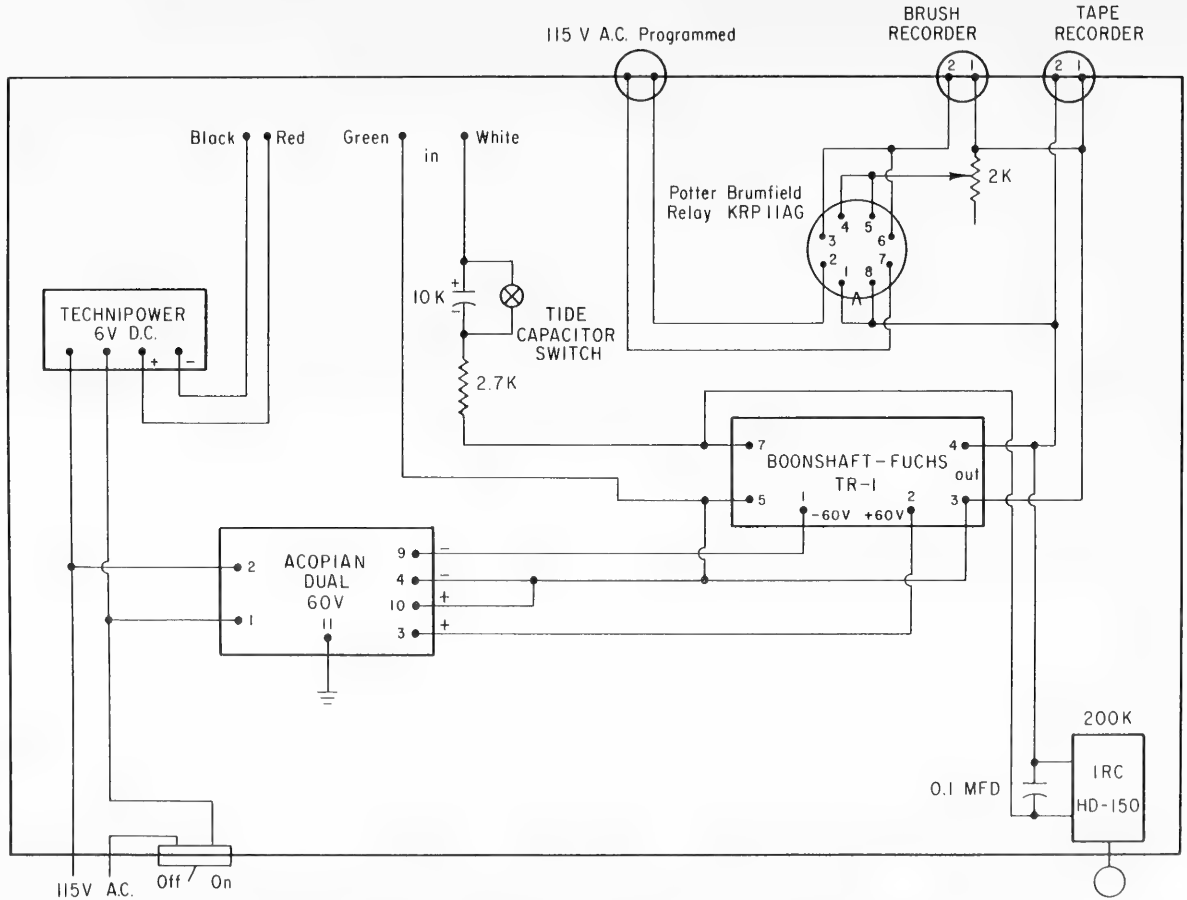


Figure 38. Amplifier Power-Supply Unit for Pressure Gage.

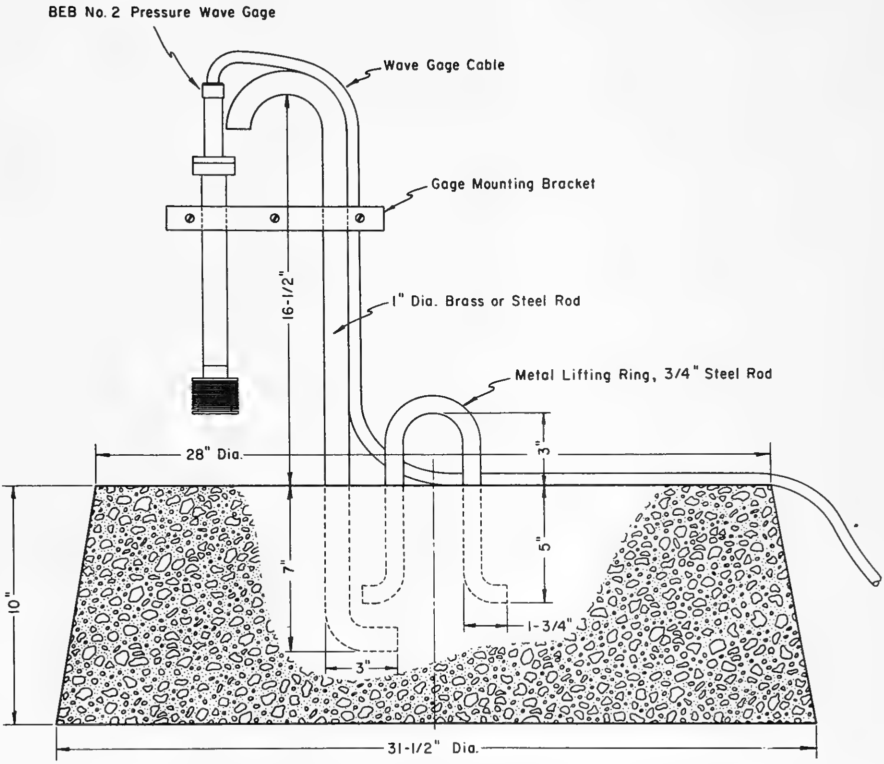


Figure 39. Concrete Block for Mounting Pressure-Sensitive Gage.

3. Operation of Pressure-Sensitive Gage

a. Calibration

Perform the following steps in the given order for pressure-gage calibration:

a) Connect the strip-chart signal cable to the amplifier-power-supply unit.

b) Set the tide-capacitor switch to the "capacitor-out" position (switch contacts closed).

c) Apply power to the recorder and the amplifier-power unit.

d) Adjust the d.c. voltage out of each 60-volt power supply to exactly 60 volts.

e) Adjust the d.c. voltage out of the 6-volt power supply to exactly 6 volts.

f) Remove power from amplifier-power unit and strip-chart recorder.

g) Connect wave sensing-unit cable to the four binding posts on amplifier-power-supply unit. Be sure that the color code on the binding post has been carried to the same color code on the Sanborn linear-differential transformer inside the pressure-sensing unit.

h) Set dial on the 10-turn variable resistor on the amplifier-power unit to its counterclockwise (lowest resistance) position.

i) Apply power to amplifier-power unit and strip-chart recorder.

j) Adjust pen on the strip-chart recorder to center of recording chart with lever on side of penmotor.

k) Decide the maximum wave height to be recorded and divide by two.

l) Lower gage 1 foot into still water and readjust recorder pen to center of chart paper with lever on side of pen-motor.

m) Lower gage into water one-half of the wave height expected to be recorded. Value found in step k above.

n) Adjust 10-turn variable resistor clockwise until recorder pen moves to full scale.

o) Repeat steps j, l, m, and n above.

p) Place tide-capacitor switch to "in" position (switch open).

q) Tide capacitor will begin to charge, and recorder pen will slowly return to center of paper. When capacitor has charged as indicated by recorder pen returning to the center of the chart, quickly submerge the gage for the remaining one-half value of maximum wave height expected. Recorder pen should again move to full scale on recorder chart. Quickly move gage to a depth of 1 foot. Recorder pen should move to opposite side of chart paper.

r) To check gage linearity, place tide capacitor switch to "out" position. Place gage in 1 foot of water. Move recorder pen to side of chart paper with lever on side of penmotor. Submerge gage in 1-foot steps for full wave height. Slight adjustment of the 10-turn variable resistor may aid in setting linearity and full scale.

s) Record the dial reading on 10-turn variable resistor and lock dial.

t) Place gage in 1 foot of water. Re-center recorder pen on strip chart. Place tide-capacitor switch to "in" position.

u) Gage calibration is complete; calibration may be plotted on graph paper for further use.

If facilities are available, calibration of the gage may be carried out by using compressed air. Such facilities for calibration would include an airtight chamber for housing the gage. This chamber should be large enough so that it does not mechanically hinder the gage bellows. A precision pressure gage with a suitable source of compressed air and air valves may be used to apply the same pressure to the air chamber as would be developed by the water depth. Calibration procedures would then be performed as outlined above, substituting equivalent air pressure for water depths.

b. Installation

Consideration should be given to the type cable required for use between the pressure-sensing unit and the recording equipment located on shore. If the surf zone is of sand, it may be possible to use 4-conductor No. 14 AWG cable having a neoprene outer jacket. This type of cable should be taped parallel to an ordinary 1/2" diameter steel cable through the zone of wave action. The weight of the steel cable

should cause the cable to sink well into the sand in the surf area. Slack should be left in the cable to permit it to sink.

If the cable must pass through a rocky (or impermeable) zurf zone, it may be necessary to use armored cable through the area where wave action will be directly on the cable.

Cable used under water should be pressure-tested for leaks prior to use. Most cable suppliers will make the pressure test when requested.

The short length of cable attached to the pressure-sensing unit should be spliced to the cable from shore using a 3-M No. 82A1 cable splicing kit.

The wave-sensing unit should be mounted to its support using the plastic brackets shown in Figure 35. These brackets are required to prevent galvanic action from corroding the sensing unit. The gage cable should be taped firmly to the gage support at the point where the cable leaves the brass gage case. If this is not done, wave action will flex and break the cable.

Laying the cable from the recording site to the offshore sensing point requires planning based on the gage location on the seabed. Coiling the cable in a figure 8 on deck of the boat, barge, or other vehicle will allow the cable to pay out without twisting. It may be desirable to lay the cable, and then splice the gage to the end after it is in place. The splice requires about 30 minutes to harden before placing under water.

After the gage is in its operating location and the cable laid to the recording site, install the amplifier-power unit, the strip-chart recorder, chart rewind, programmer, and magnetic tape recorder (if used) and connect them as shown on Figure 40. The color code of the leads from the Sanborn linear differential transformer must be carried to the corresponding binding posts on the amplifier-power unit.

After the gage system is connected as outlined above, apply power to the amplifier-power unit, strip-chart recorder, and magnetic-tape recorder, chart rewind, and the gage is ready for operation. The 10-turn variable resistor dial should be set to the value obtained in the calibration procedure, and the tide-capacitor switch should be set in the "in" position (switch open).

When the gage is first placed in operation, the recorder pen will probably be off scale, since the tide capacitor is not in a charged condition. The off-scale condition of the recorder pen is normal, and the pen will slowly return to its normal position (center of chart) as the tide capacitor charges. The tape recorder signal meter will also be off scale as outlined above until the tide capacitor charges.

The programmer should be adjusted to provide the desired wave-record program. The programmer will start the record at the beginning of each

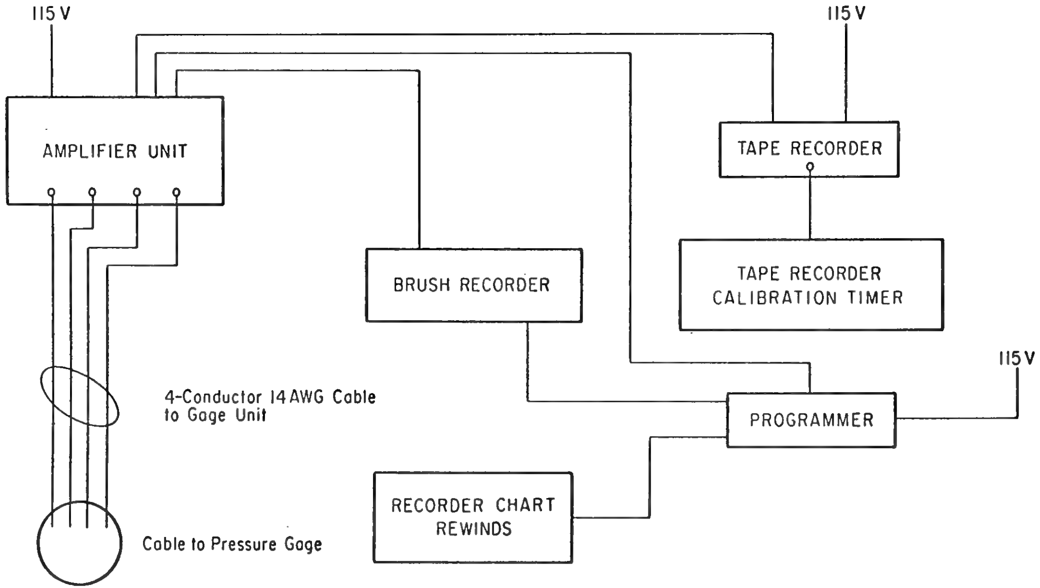


Figure 40. Diagram For Pressure-Sensitive Gage

hour for a selected number of minutes. Any hour or hours may be omitted from the recording program by removing the knurled screws from the programmer dial.

c. Maintenance

The recording station will require servicing at regular intervals to change the strip-chart recorder-paper and fill the recorder inkwell. Also the programmer should be checked for timing accuracy.

The wave-sensing unit should be raised and inspected at 6-month intervals to see whether it has been fouled by sea growth, and whether the entire gage has settled into the ocean bottom and bellows operation restricted.

Section VI. FABRICATION OF EPOXY GAGE SECTION

To make epoxy wave staff sections, a suitable mold is required. The mold is fabricated by using a room-temperature curing silicone rubber. In order to conserve the silicone rubber, a close fitting aluminum container is fabricated as shown on Figure 41. A gage section pattern is also required as shown on Figure 41, for either the relay-operated wave gage, or the other two types. The finish on the epoxy gage section will be that of the gage pattern; care should be taken to ensure a smooth surface.

RTV-630 is available in gallon cans; the kits contain the silicone rubber in one container and the curing catalyst in another. The silicone rubber is used as the mold vehicle due to its releasing properties in removing the epoxy section when hardened. Place the gage pattern in the trough as shown in Figure 41, fill the space between the pattern and the trough with the RTV-630 and allow to cure as specified by the manufacturer. Use the amount of catalyst recommended by the manufacturer. Failure to do so will shorten the pot life and cause uneven cure of the mold. Avoid trapping air in the RTV-630 while stirring and pouring as bubbles cause holes in the completed mold. The trough should be filled to the brim. If excess is above the trough and gage pattern when curing is complete, it can be trimmed with a long sharp knife. When the mold is cured, remove the gage pattern and thinly coat the inside of the mold with vaseline. Recoat mold with vaseline between gage section moldings.

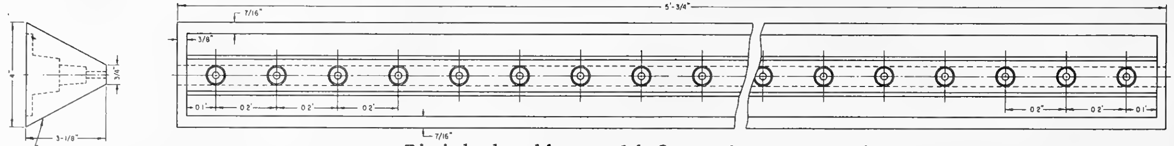
Assembly components for the desired gage section on a jig outside the mold and check them electrically. After checkout insert the components in the mold as a unit and be sure that the metal gage sensing points are in the bottom of the mold. Align the gage cable with the mold so that it will be in the correct position when the section is completed.

After the components have been placed in the mold, fill it with one-half the epoxy resin required for the gage section. Allow the section to cure 4 hours and fill the rest of the mold with epoxy resin. About 7 pounds are required for one gage section. The resin is furnished in two parts and must be mixed in equal parts by weight just prior to using. Do not allow moisture in the resin during pouring and curing as it will cause the epoxy to turn white. Even a good healthy sneeze over the mold will turn the gage section white.

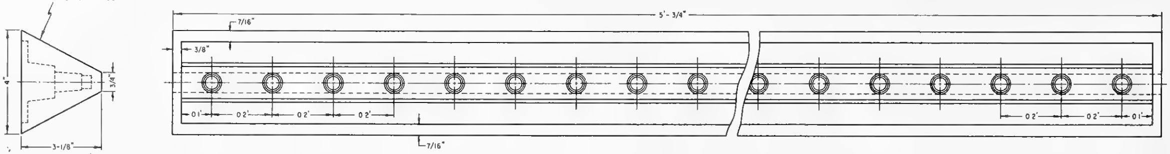
When the epoxy has cured (overnight) remove the section from the mold, clean it thoroughly and recheck it electrically. Be sure the sensing tips are not coated with epoxy.

The epoxy sections become brittle in cold weather and care should be exercised when handling to prevent breakage.

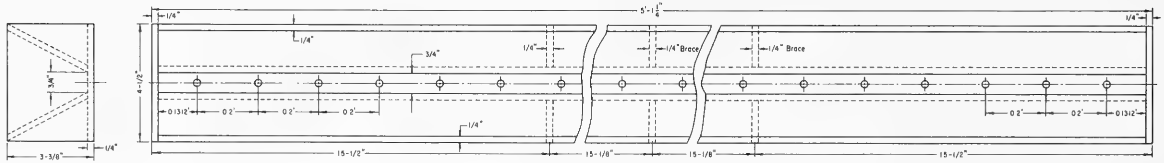
The epoxy sections should be stored in a slotted wood board to keep them from warping. If a section becomes warped, it may be straightened by heating, placing in a straight position, and allowing to cool.



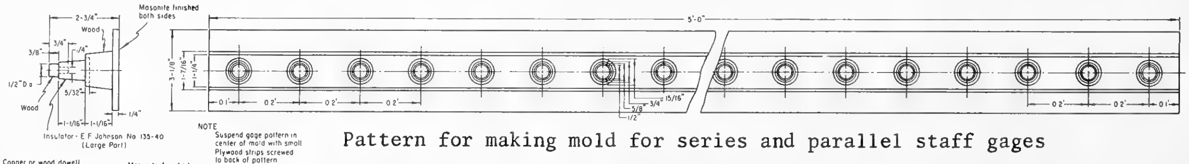
Finished rubber mold for relay-operated gages



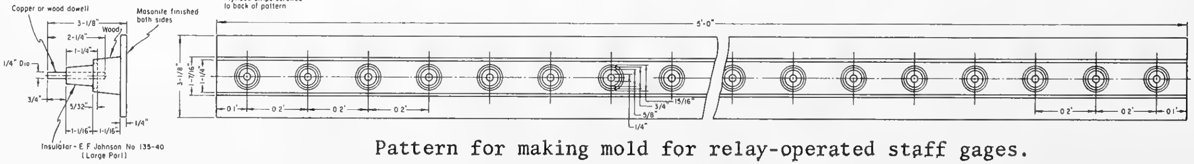
Finished rubber mold for series and parallel staff gages



Aluminum container for making mold for all staff gages.



Pattern for making mold for series and parallel staff gages



Pattern for making mold for relay-operated staff gages.

Figure 41. Patterns, container, and molds for epoxy sections for step-resistance gages.

Damaged sections may be returned to the mold and repaired by adding epoxy to the injured places.

The epoxy sections may be repaired by drilling out the defective component, replacing the component and remolding the damaged section, using the original gage mold and new resin.

If the gage mold is not used for several weeks, it may absorb moisture and cause the epoxy not to cure. Such moisture in the mold will also cause the epoxy sections to be white in color. Heating the mold for several hours should remove this moisture.

Section VII. MAGNETIC TAPE RECORDER FOR OCEAN-WAVE GAGES

1. Theory of Operation of Magnetic Tape Recorder

No commercial tape recorders are available that could be modified to serve as an analog ocean-wave recorder for long periods of time. CERC found it necessary to design and build its own tape recorders. The magnetic tape recorder Model LW-1 is designed to record ocean waves with periods of about 2 seconds through 100 seconds. Wave heights recorded full-signal on the tape recorder will be those from the wave gage that provide full-scale indication on the wave gage strip-chart recorder.

The recording signal is a d.c. analog to the recording head. Line frequency is used as the recording bias to the tape head. Thus, the recording is similar to that used on a standard tape recorder for voice or music, although a higher frequency bias is used in a standard tape recorder. However, at the wave period (frequency) at which the wave recorder operates, the line frequency (60 cycles) is more than adequate.

The recording signal (wave-gage signal) from the three types of step-resistance wave gages is a 0 to 30-volt d.c. analog. This signal is equal to zero submergence and full submergence, respectively, of the wave staff, thus the signal is proportional to the water level on the wave staff. The tape recorder has a 10,000 microfarad capacitor to remove the average d.c. signal from the wave-staff signal to prevent this average signal from reaching the recording tape head. This, in effect, removes the change in gage signal caused by tidal changes. Removal of this tide signal from the gage signal allows a wider dynamic range of the wave signal to be applied to the tape head, resulting in a better wave recording on the magnetic tape.

The wave-gage signal from the pressure-sensitive wave gage has the tide component removed from the gage signal in the amplifier-power supply unit by a high-value capacitor in much the same manner as is done in the tape recorder. The output (wave-gage signal) from the amplifier-power unit is a d.c. analog of 15 0 +15 volts. This signal is proportional to the trough-to-crest wave height for the respective maximum wave height for which the pressure-sensitive unit is calibrated. This signal will produce full-scale movement of the recorder pen on the strip-chart recorder, and is used as the wave signal to the tape recorder. Therefore, the tide removal capacitor in the tape recorder is not required when the recorder is used with the pressure-sensitive gage.

To operate the tape recorder with both types of wave gages (staff and pressure), one requiring tide removal, the other not, there is a switch in the tape recorder for bypassing the tide capacitor. It is labeled tide capacitor "in-out".

The magnetic tape recorder may be operated with other wave-gaging systems provided those gages produce a d.c. analog signal proportional

to wave height. The d.c. analog should be 0-5 volts at 1 milliampere. Lower signals will attenuate longer period waves excessively.

Bias signal amplitude, held constant by a constant voltage harmonic-neutralized transformer, is passed through a resistance-capacitor filter to further improve the wave form before it goes to the recording head.

The recorder is designed to use Minnesota Mining and Manufacturing Company No. 428 magnetic tape 1/4 inch wide, on 1,250-foot reels. One reel of tape will record continuously for about 3 weeks. The tape speed used is one-half inch per minute. In normal recommended operation at CERC recording wave stations, the magnetic tape recorder operates continuously.

Tape-recorder engineering design data was not available regarding the slowest speed that could be used. The minimum tape speed, tape-head gap, and bias frequency, needed to record 2-second waves in the field had to be developed in the CERC laboratory.

To provide a section of tape long enough for analysis on the CERC spectrum analyzer, a recording must be at least 20 minutes long. While a 20-minute record may be analyzed, a 24-minute record is recommended.

The recorder has a built-in calibrating signal (sine wave) with a period of 4 seconds. This signal, usually recorded for 30 minutes twice each day at 10 a.m. and 10 p.m. local standard time, is used to check recorder operation and to standardize input to the laboratory spectrum analyzer. The amplitude of the calibrating signal is adjustable to provide the same signal on the magnetic tape as the full-scale signal provided by the wave gage. The calibrating signal is programmed by a timer plugged into the recorder chassis. A switch is provided on the front of the tape recorder to permit the user to place the calibrating signal on the tape at his selection. This signal must also be 20 minutes or longer.

The recorder does not have an erase head; magnetic tape used must be free of all recordings prior to use. When ordering, specify that tape shall be of virgin quality and free of all test recordings. Tape should be shipped in steel cans to aid in avoiding magnetic fields while in transit.

Numbered, small, adhesive markers must be placed on the section of tape that is directly over the tape head when the tape is installed and just before it is removed. Additional markers should be similarly placed on the tape at significant times. Markers should be logged, listing the exact time of placement and any pertinent comments. These markers and the data logs are the only means of identifying the time of recorded wave data; their importance cannot be overemphasized.

Two meters are incorporated in the recorder to adjust and monitor its operation. One has a zero center pointer, and indicates the amplitude of the waves at the tape recorder. A meter movement of 400-0-400

is selected for full signal wave conditions from the wave gage. The other indicates the current in the record head from the bias signal, and is normally adjusted to provide a reading of 0.8 volt which corresponds to 8 milliamperes of bias current in the recorder tape head.

2. Fabrication of Magnetic Tape Recorder

Parts required for the CERC LW-1 tape recorder are listed in Table X. Details of fabrication are shown in Figures 42 through 45.

The mechanical items should be assembled to the chassis and panel assembly. Particular care is required in aligning each electric motor shaft and the driven shaft. Use of 1/4-inch rod drilled with a 3/16-inch hole in one end through the panel bearings should aid in getting good alignment of the motor shafts. Use of a similar rod drilled with a 1/8-inch hole in one end should aid in aligning the calibrating signal drive motor (15 r.p.m.) with the synchro shaft. When the proper alignment is reached, the flexible couplings should receive the driven shafts without binding. Binding at this point will cause early failure of the flexible coupling. The panel shaft bearings should be cleaned, and given a drop of light oil during assembly.

Wiring of the recorder is shown on the schematic diagram on Figure 46. The wiring placement is not critical in obtaining proper operation. Good wiring practice is all that is required.

The constant-voltage transformer is mounted in the left rear of the recorder cabinet. Input and output cables must be installed on the transformer to provide proper connection to the plugs on the rear of the recorder chassis.

A signal cable for the tape recorder is fabricated to the desired length using 2-conductor No. 18 AWG and two amphenol No. 80-MC2-M connectors.

Care is required in connecting the outer terminals of the three potentiometers on the front panel to provide increased signal conditions when the potentiometer shafts are turned clockwise.

The tape-supply spool shaft uses a spring and washer assembly to provide tension to the tape. The tension of this spring should be adjusted to provide a very light pull on the unwinding tape. If too little tension is applied to the rewinding tape, the tape will skew on the capstan and foul the tape drive. Correct tension is just above that required to prevent tape skew.

Ferrous parts used in the tape transport, including the recording head, should be demagnetized after assembly. If the tape head is magnetized, or if the tape is placed close to a magnetized object, the tape recording will be of poor quality or may even be erased.

Text resumes on page 93.

TABLE X

LIST OF COMPONENTS FOR MAGNETIC TAPE RECORDER, LW-1

1.	Magnetic Tape Recording Head, Brush #BK-1250	1 ea.
2.	Motor, Hurst SM 1/2-1/2 RPM (Clockwise rotation)	2 ea.
3.	Motor, Hurst SM-15, 15 RPM, either right or left rotation	1 ea.
4.	Direct Current Microammeter - 500-0-500, Simpson Model #29	1 ea.
5.	A.C. Voltmeter 0-1 Volts - 1,000 ohms per volt, Simpson Model #49	1 ea.
6.	Cabinet-Bud, No. CR-1742-HG Gray Hammertone finish	1 ea.
7.	Transformer, Sola, No. 23-13-060 Harmonic neutralized type	1 ea.
8.	Transformer, Stancor P-6469	1 ea.
9.	Transformer, Stancor P-6134	1 ea.
10.	Transformer, Stancor PS-8416	1 ea.
11.	Potentiometer, wire wound, 5,000 ohms, Mallory M5MPK	1 ea.
12.	Potentiometer, wire wound, 2,000 ohms, Mallory M2MPK	2 ea.
13.	Potentiometer, wire wound, 25,000 ohms, Mallory M25MPK	1 ea.
14.	Relay, Potter Brumfield, No. MR11A-DPDT-115 volt, 60 cycles	1 ea.
15.	Autosyn, No. AY-201-3-B	1 ea.
16.	Cord Set, Belden #17460-S	1 ea.
17.	Cable, Belden #8452	7 ft.
18.	Resistor, wire wound, 1 watt, IRC, ±10%, 1,000 ohms	8 ea.
19.	Resistor, wire wound, 1 watt, IRC, ±10%, 1,200 ohms	1 ea.
20.	Resistor, wire wound, 1 watt, IRC, ±10%, 560 ohms	2 ea.
21.	Switch, SPST, Arrow Hart & Hegeman, No. 20994-BF	3 ea.
22.	Rectifier - 1N2070 or 1N1692	2 ea.
23.	Capacitor - 100 MFD-50 volts, Aerovox PRS	2 ea.

TABLE X (continued)

24.	Resistor - 1 watt, wire wound, IRC - 2,000 ohms	2 ea.
25.	Capacitor - Paper 2MFD, 200 volts - Aerovox P82Z	4 ea.
26.	Idler, Wheel, Walsco, No. 1488	1 ea.
27.	Coupling, Millen No. 39016	2 ea.
28.	Spring-General Cement, No. H412-F	1 ea.
29.	Snap Button-Hole Plug, General Cement, H308-F	3 ea.
30.	Chassis, Aluminum 10" x 17" x 4", Bud AC 427	1 ea.
31.	Socket, Octal, Amphenol 78RS8	1 ea.
32.	Plug, Harvey Hubbell No. 7485	1 ea.
33.	Plug, Harvey Hubbell No. 7484	1 ea.
34.	Plug, Harvey Hubbell No. 7486	1 ea.
35.	Plug, Harvey Hubbell No. 7487	1 ea.
36.	Connectors, Amphenol, male plug 80-MC2M	2 ea.
37.	Connectors, Amphenol, female receptacle 80-PC2F	1 ea.
38.	Capacitor, Mallory, No. HC10100, 10,000 MFD, 10VSP	1 ea.
39.	Bearing, Bost-Bronze, oil-impregnated bronze, Boston gear No. FB-46-6	3 ea.
40.	Resistor 111 ohms ±1%, 1 watt, Precision Resistor Company 109 U.S. Highway, Hillside, New Jersey.	1 ea.
41.	Plug 3-prong male with shell amphenol #160-5	1 ea.
42.	Bearing assembly TV. Contro-Roller as per Columbia Wire Supply Co., 2850 Irving Park Road, Chicago, Illinois.	1 ea.
43.	Nameplate, brass (as desired)	1 ea.
44.	Grommets, Smith 2174	2 ea.

NOTE: List does not contain raw material for machining tape guides, tape capstan, flexible coupling for synchro, nuts, bolts, hookup wire, or terminal strips.

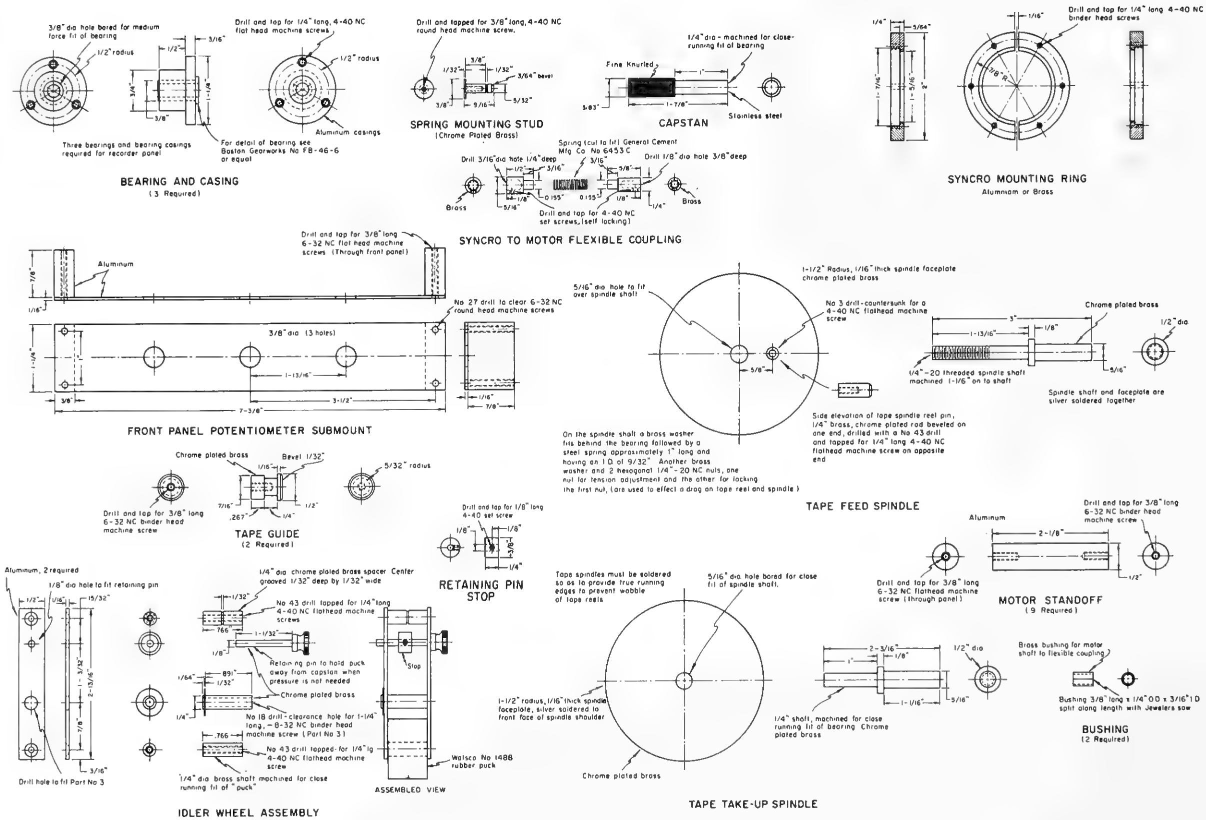


Figure 42. Parts for Magnetic Tape Recorder, LW 1.

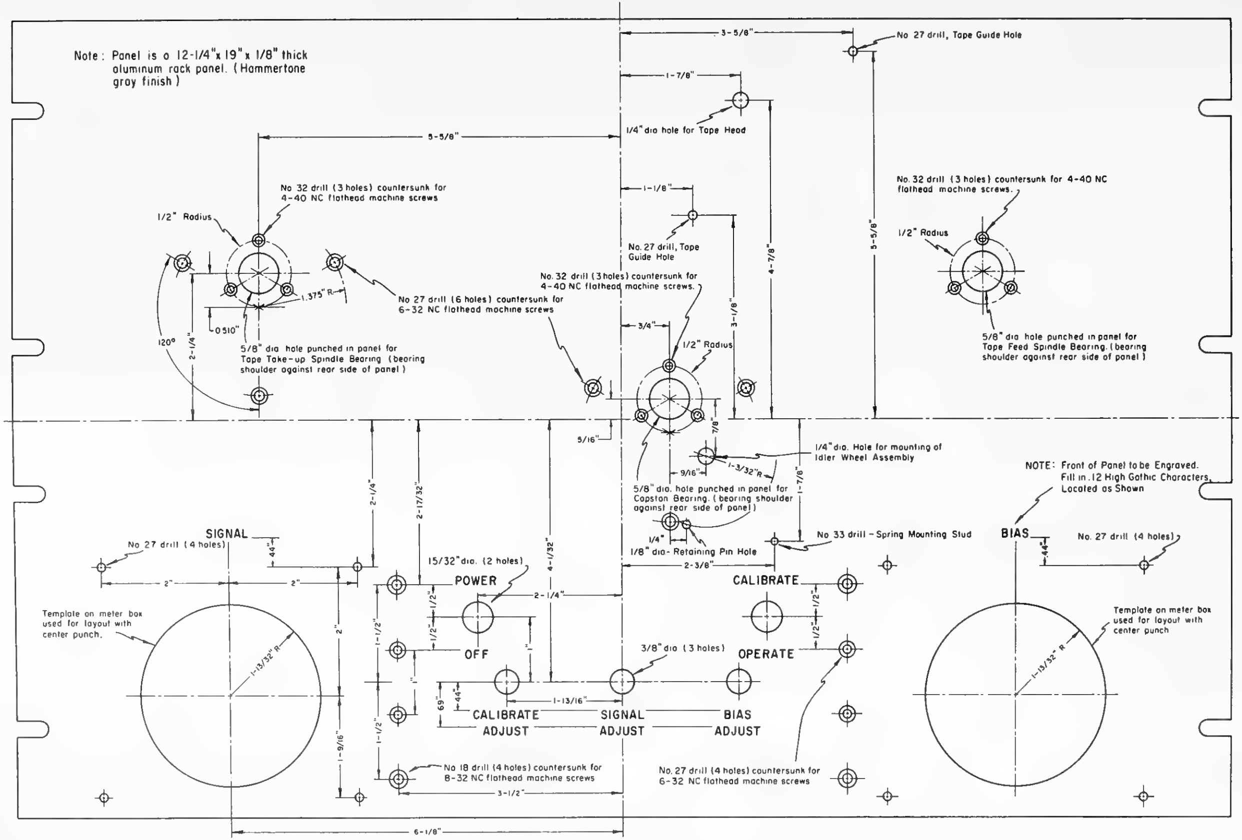


Figure 43. Magnetic Tape Recorder Panel Layout, Model LW-1.

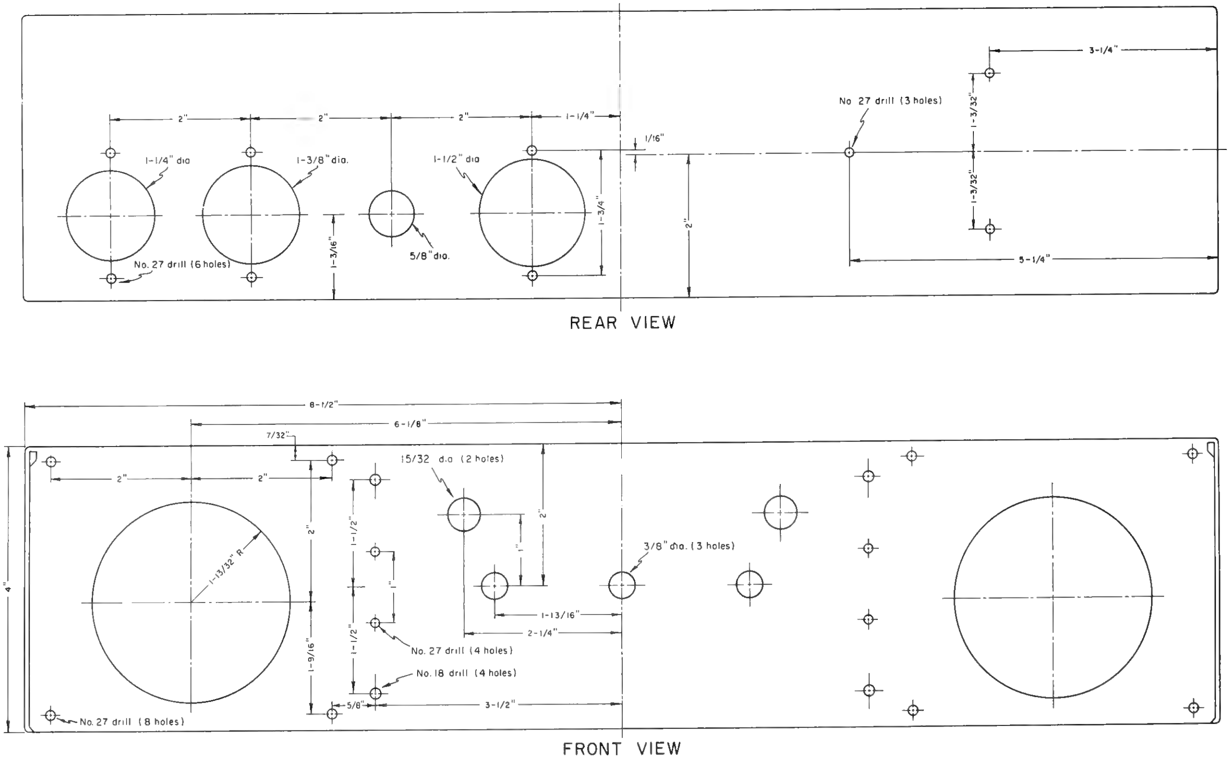


Figure 44. Chassis layout for Model LW-1 Magnetic Tape Recorder rear and front views.

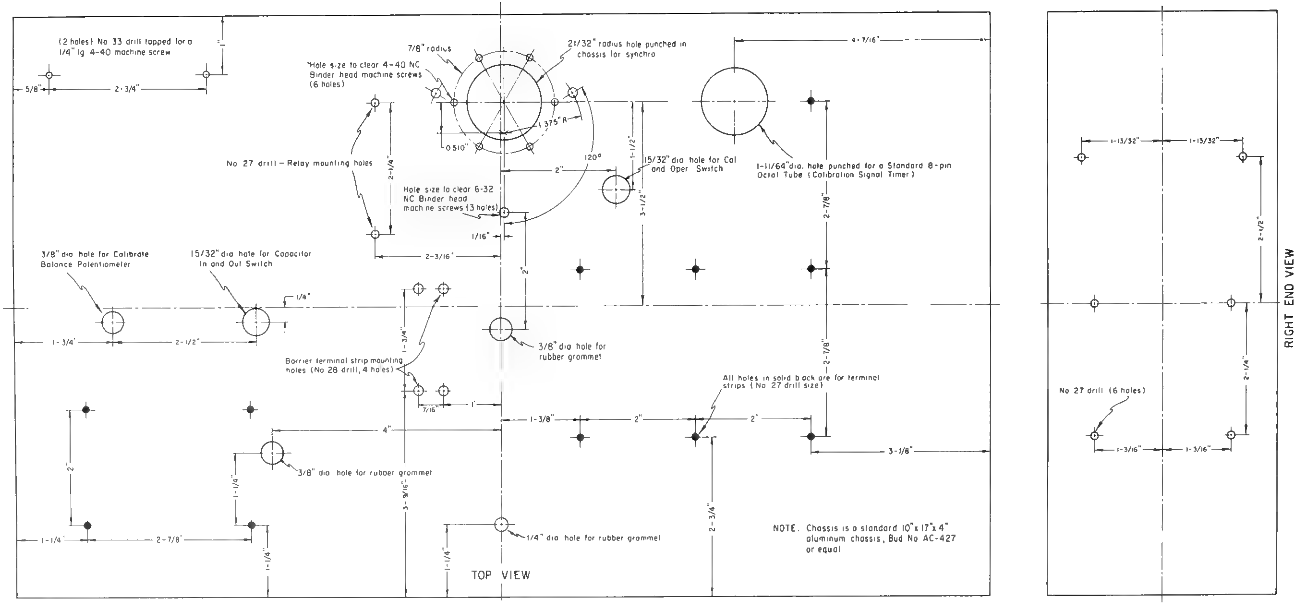


Figure 45. Chassis layout for Model LW-1, top view.

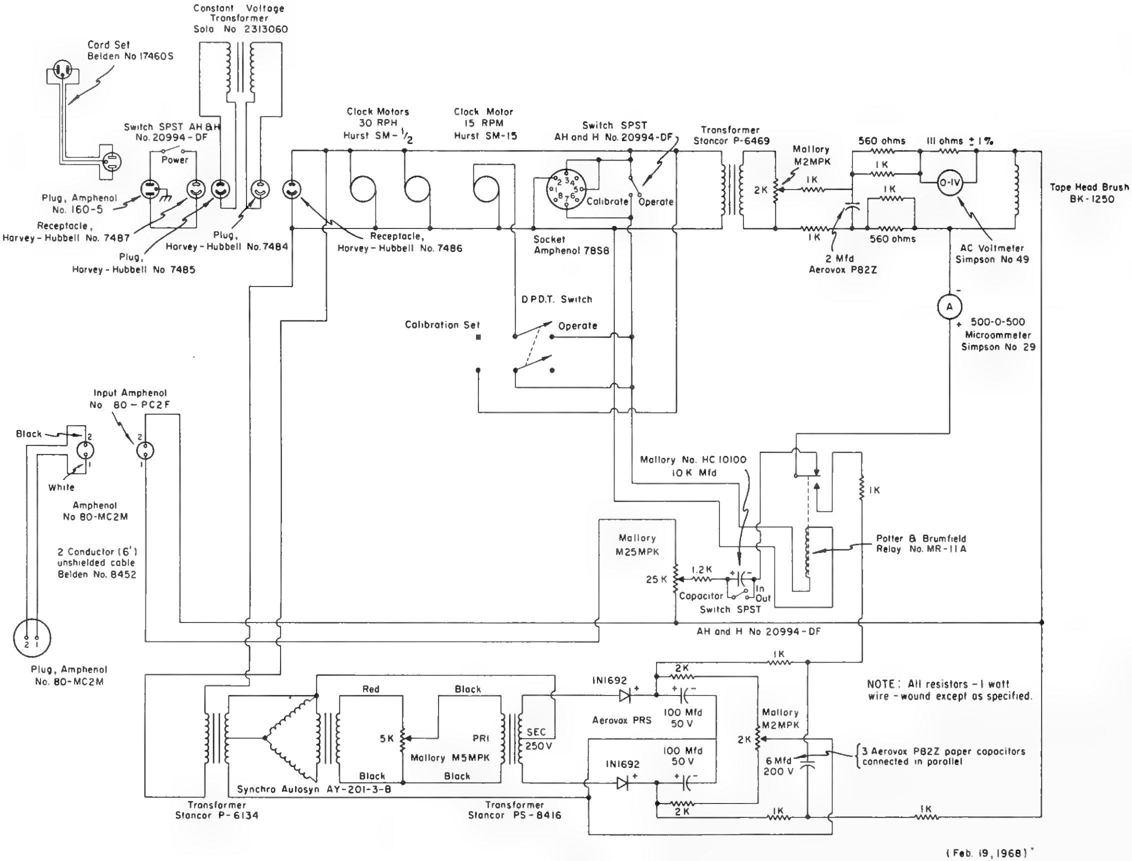


Figure 46. Schematic diagram for magnetic tape recorder, Model LW-1.

The spring for tensioning the rubber idler against the tape capstan should be designed to place a firm pressure on the tape. If the tension is insufficient, it will allow the tape to be pulled through the capstan roller by the take-up reel, resulting in a tape speed too fast for proper recording.

If the tape recorder is turned off, the capstan roller must be backed off from resting on the capstan. If the roller is allowed to stand on the capstan with pressure, the rubber roller will indent permanently and be rendered useless. Removal of pressure on the capstan is accomplished by placing a pin through the roller bracket into a hole drilled in the front panel.

The recorder requires a timer for placing the internal calibration signal on the tape automatically. Figure 47 shows assembly and wiring of this timer. The timer cable plugs into the octal socket on top of the tape-recorder chassis. Calibration of the tape recorder requires a calibration unit which is fabricated according to Figure 48. Parts required are listed in Table XI.

3. <u>Calibration and Operation</u>

The wave signal from the gage must have an amplitude that will provide a current of 0.8 milliampere through the magnetic tape head. The voltage level from the wave gage should be greater than 5 volts for the tide capacitor in the tape recorder to have an adequate time constant. The wave signal from the CERC wave gages is more than that required, and the signal level is reduced and adjusted by the potentiometer in the lower center adjusting-port in the front panel of the tape recorder. See Figure 49.

The bias frequency to the tape head must be 8.0 milliamperes, and is adjusted by the potentiometer located through the port on the bottom right from center panel position.

The internal 4-second period calibration signal also must provide 0.8 milliampere through the magnetic tape head. This signal will be indicated by the left meter on the tape recorder panel. The meter will swing 400-0-400 microamperes when properly adjusted. A centering control on the inside chassis of the recorder is provided to center the calibration signal on this meter.

Calibrate the tape recorder by the following steps:

a) Turn all controls recessed in the three ports in the bottom center of the recorder panel to their counterclockwise positions.

b) Set the centering control on the recorder chassis to its midpoint of rotation.

Text resumes on page 98

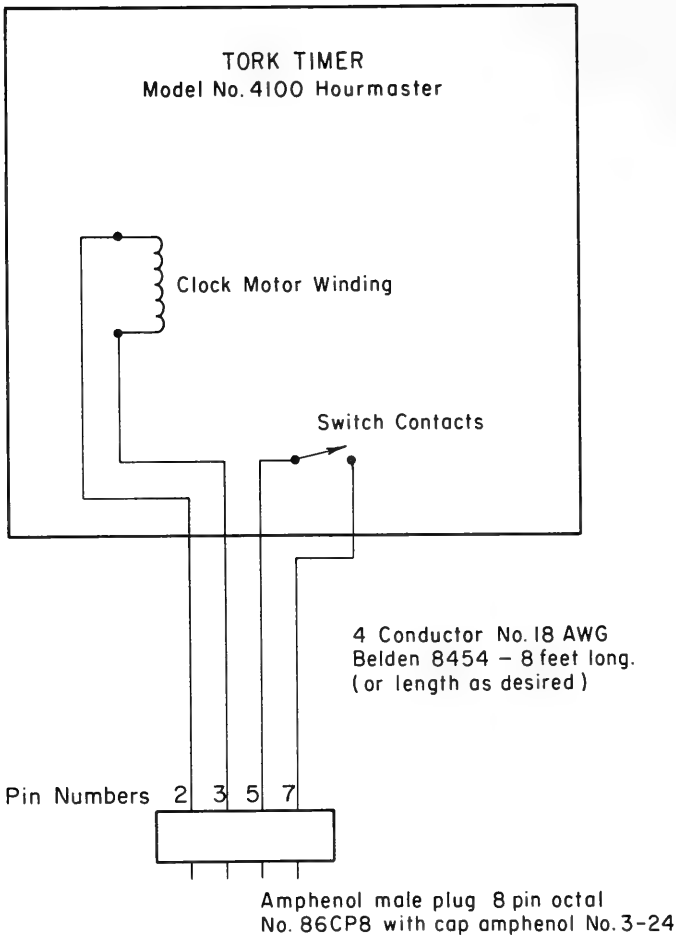


Figure 47. Calibration signal timer for magnetic tape recorder.

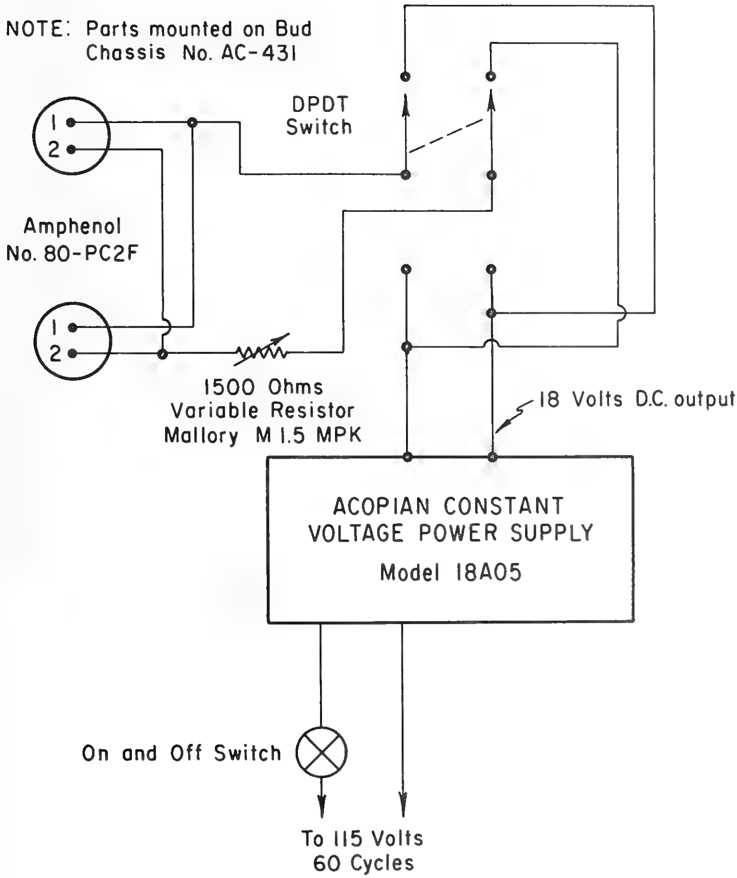


Figure 48. Diagram of Calibration Unit.

TABLE XI

PARTS REQUIRED FOR A CALIBRATION UNIT FOR CALIBRATION OF A TAPE RECORDER WITH A STRIP-CHART RECORDER

1.	Power Supply Output, 18 volts d.c. at 50 milliamperes input 115 volts, 60 cycle, Acopian Technical Company, 927 Spruce Street, Easton, Pennsylvania, Model H 18A05, or equal.	1 ea.
2.	Potentiometer 1,500 Ohms, 4 watt, Mallory M1.5MPK, or equal.	1 ea.
3.	Switch DPDT, Arrow Hart & Hegeman #20905 FR, or equal	1 ea.
4.	Female receptacle, Amphenol #80-PC2F, or equal	2 ea.
5.	Chassis aluminum, 4" x 6" x 3" Bud AC-430, or equal	1 ea.
6.	Line cord, Belden, 17408S, or equal	1 ea.
7.	Knob Nation Co. HR, or equal	1 ea.
8.	Switch SPST, A-H & H #20994LH, or equal	1 ea.
9.	Rubber grommet for line cord	1 ea.

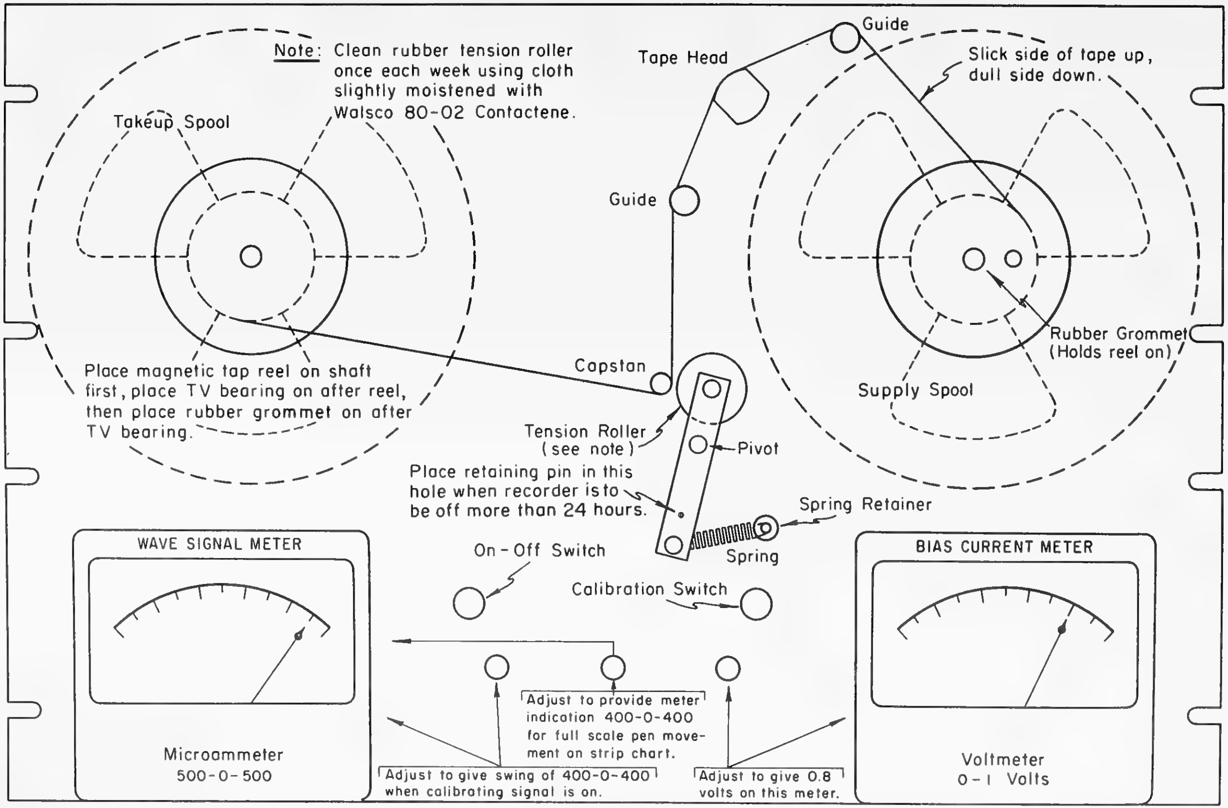


Figure 49. Magnetic Tape Recorder, Model LW-1

c) Apply power to the recorder, and set the "calibrate-signal" switch on the front panel to the "calibrate" position.

d) Adjust the right adjusting potentiometer on the front panel to provide a reading of 0.8 volts on the right panel meter.

e) Adjust the left potentiometer on the front panel to provide a swing of 400-0-400 on the left meter. If the meter does not swing equally on each side of zero, adjust the centering control on the recorder chassis to obtain equal movement of the meter pointer on each side of center. Due to the inertia of the meter movement, the meter pointer will not provide an accurate indication of the actual current in the meter. To get the precise peak pointer-movement of the meter, it is necessary to stop the synchro shaft at its peak signal point of rotation. To do this, set the switch on the chassis near the synchro to the "calibrate" position, and grasp the coupling attached to the synchro shaft and turn it manually to provide peak indication on the left panel meter. Adjust the panel control for the proper 400-0-400 movement of the meter corresponding to the physical location of the synchro shaft that produces maximum swing of the meter. The centering control may require further adjustment at this time. *Adjustment of the calibration signal is very important as it is used to standardize the wave gage signal and the spectrum analyzer in the CERC laboratory.* Return the calibrate switch near the synchro to its "operate" position when the above adjustment is completed.

f) Connect the signal cable from the magnetic tape recorder and the signal cable from the strip-chart recorder to the calibration unit as shown on Figure 50.

g) Set the voltage-control potentiometer on the top of the calibration unit to its counterclockwise position.

h) Apply power to the tape recorder and strip-chart recorder, and set the calibrate switch on the front panel to "off".

i) Adjust the strip-chart recorder pen to the center line on the recording chart using the manual control on the penmotor.

j) Place the tide-capacitor switch on the tape recorder chassis to the "out" position (switch closed).

k) Apply power to the calibrate unit, and adjust the strip-chart recorder pen for full-scale indication (one-half of chart width) using the voltage-control potentiometer on the calibration unit.

l) Adjust the bottom center control on the tape recorder panel to

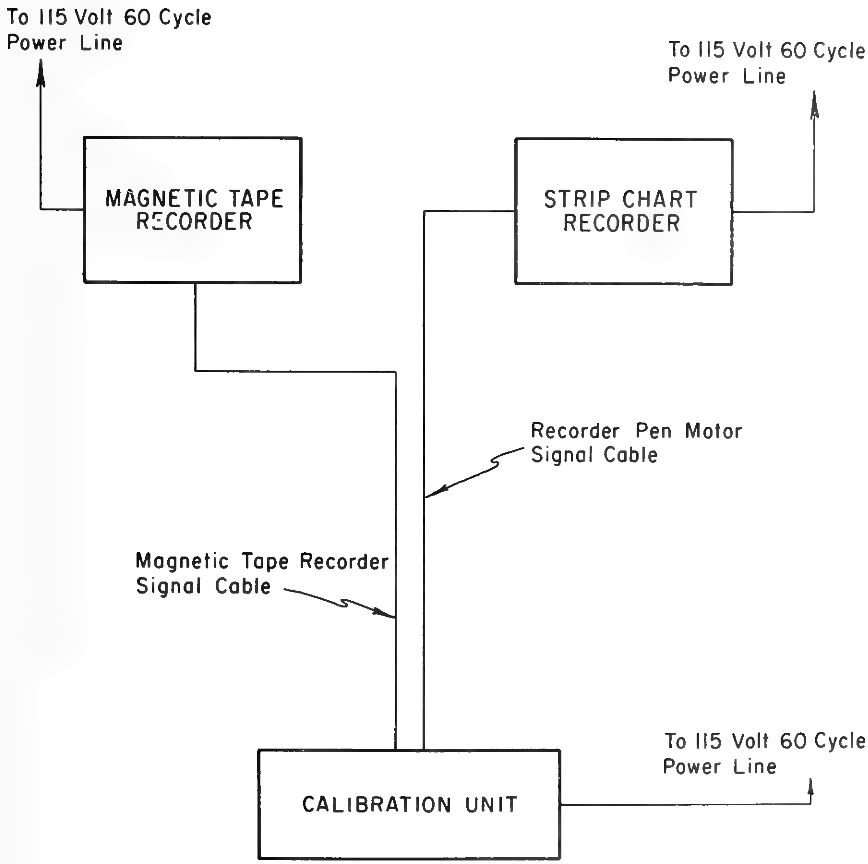


Figure 50. Block Diagram of Calibration hookup.

provide an indication of 400 microamperes on the left magnetic tape recorder meter.

m) Move the polarity-reversing switch on the calibrate unit to its other position. The strip-chart recorder pen should indicate full scale on the other side of the chart paper, and the magnetic tape recorder signal meter should indicate 400 microamperes on the opposite side of zero from that found in l) above.

n) Readjust the bias meter signal to 0.8 volt. When switching from "operate" to "calibrate", the bias meter will change slightly; this is normal, and will not affect recorder operation.

o) The magnetic tape recorder is now calibrated for full-scale recording of the signal that produces full-scale movement of the strip-chart recorder pen. Since the strip-chart recorder pen indicates the maximum wave height produced by the wave gage, the magnetic tape recorder is also so calibrated.

Since all strip-chart recorders do not have the same sensitivity, the wave-gage circuitry is adjusted to overcome this deficiency when the wave gage is calibrated. Therefore, the calibration of the magnetic tape recorder must be mated with the calibration of the strip-chart recorder with which it operates.

Section VIII. MODIFICATION OF STRIP-CHART RECORDER SPEED

The slowest speed of the chart on the recorder as received from the manufacturer is 5 millimeters per second or about 12 inches per minute. To conserve chart paper and lengthen the time between visits to the wave recording station, it is desirable to change the chart speed to a lower value.

Three lower chart speeds can be provided for the recorder with fairly simple changes in the gears. These changes will provide a basic chart speed of 2.5 millimeters per second, 1.25 millimeters per second, or 1.0 millimeter per second.

Recorder paper comes in rolls 300 feet long on GSA schedule from Judson Bigelow, Inc., 12-12 44th Avenue, Long Island City, New York, Chart No. RA-2911-30 JB. With the recorder operating for 7 minutes each 4 hours and the reduced chart speed of 2.5 millimeters per second, a 300-foot roll will last about 14 days. If different frequency recording periods are desired, the time span for one roll may be calculated.

If the recorder is modified to a slower chart speed, wave crests will appear closer together on the chart. A sample of wave periods, using sine waves, on a recorder chart with speeds of 2.5 millimeters, 1.25 millimeters, and 1.0 millimeter per second are shown on Figures 51, 52, and 53.

To modify the recorder chart speed, proceed as follows:

a) Fabricate the required gear assemblies and parts for the selected chart speed as shown on Figures 54 through 56.

b) Remove the recorder pen.

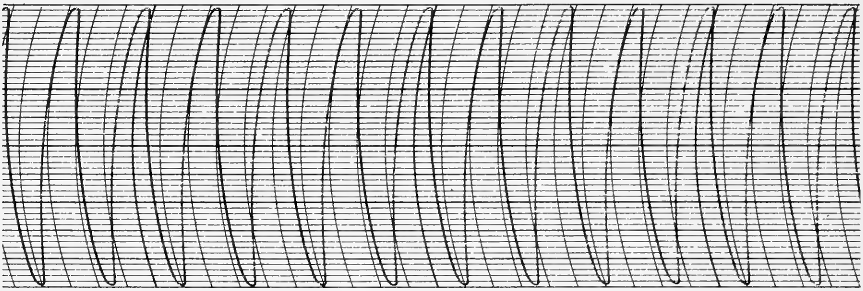
c) Remove the chart platen.

d) Remove the chart payout guide and paper tear-off unit.

e) Remove the chart driving roller, taking care not to lose the two brass spacers on the ends of the roller.

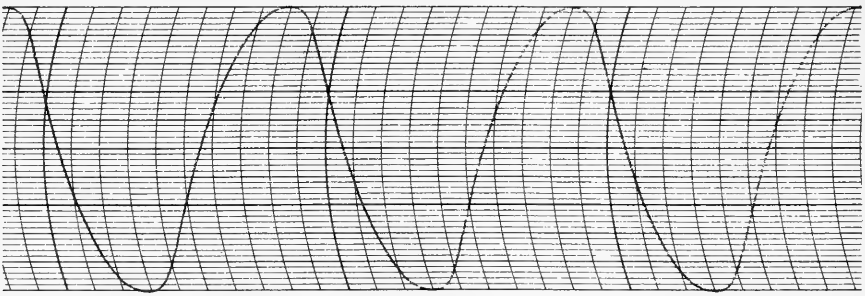
f) Remove the chart speed-shift knob assembly. A thin knife blade in the side of the main drive-shaft slot will accomplish this.

g) Remove the snap spring on the main drive shaft. Observe the spacing between the spring and the recorder frame, and retain this distance when recorder is re-assembled.



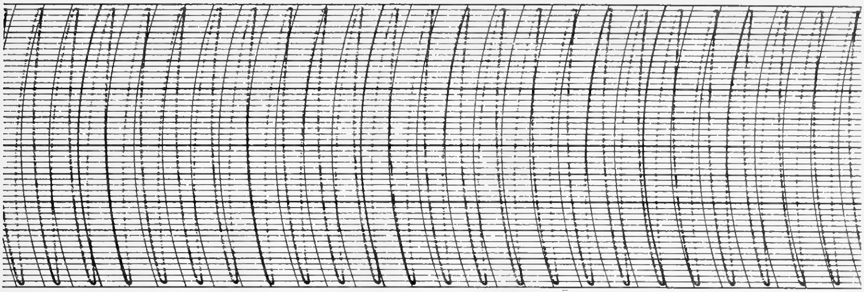
5-Second Wave Period

10-Second Wave Period

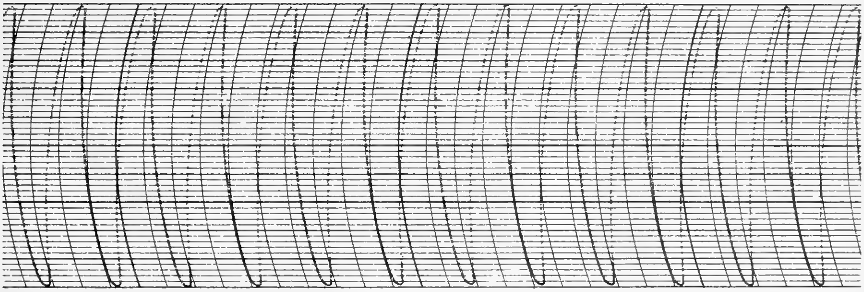


20-Second Wave Period

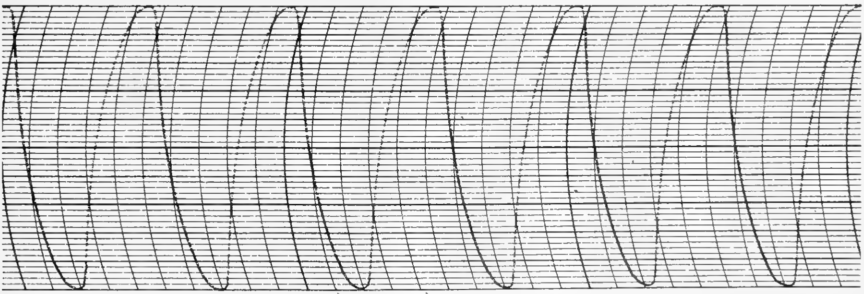
Figure 51. Wave records with chart speed of 2.5 millimeters per second



5-Second Wave Period

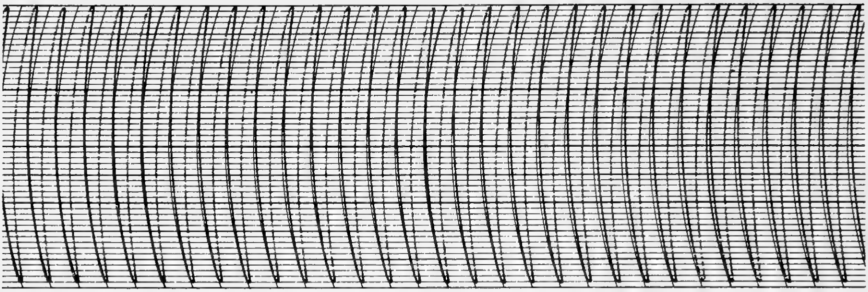


10-Second Wave Period

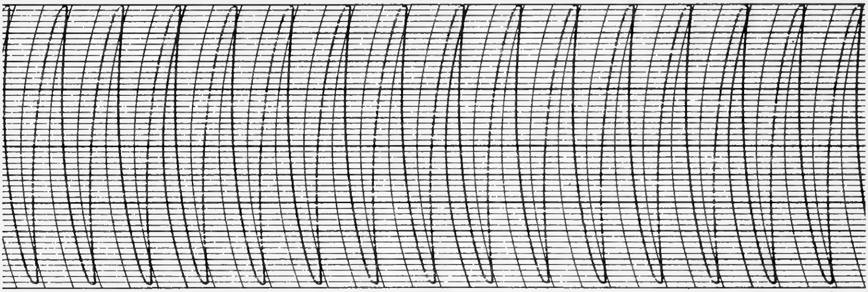


20-Second Wave Period

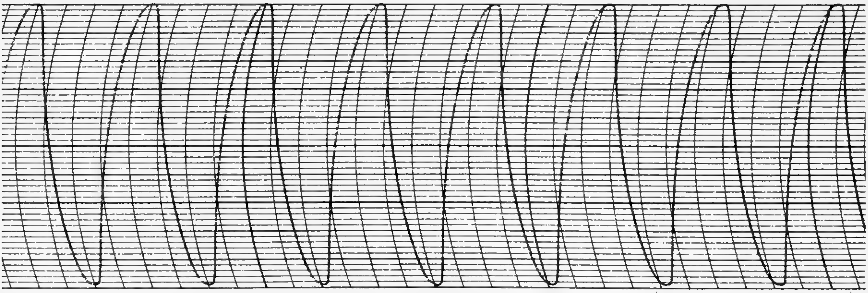
Figure 52. Wave records with chart speed of 1.25 millimeter per second.



5-Second Wave Period



10-Second Wave Period



20-Second Wave Period

Figure 53. Wave records with chart speed of 1.0 millimeter per second.

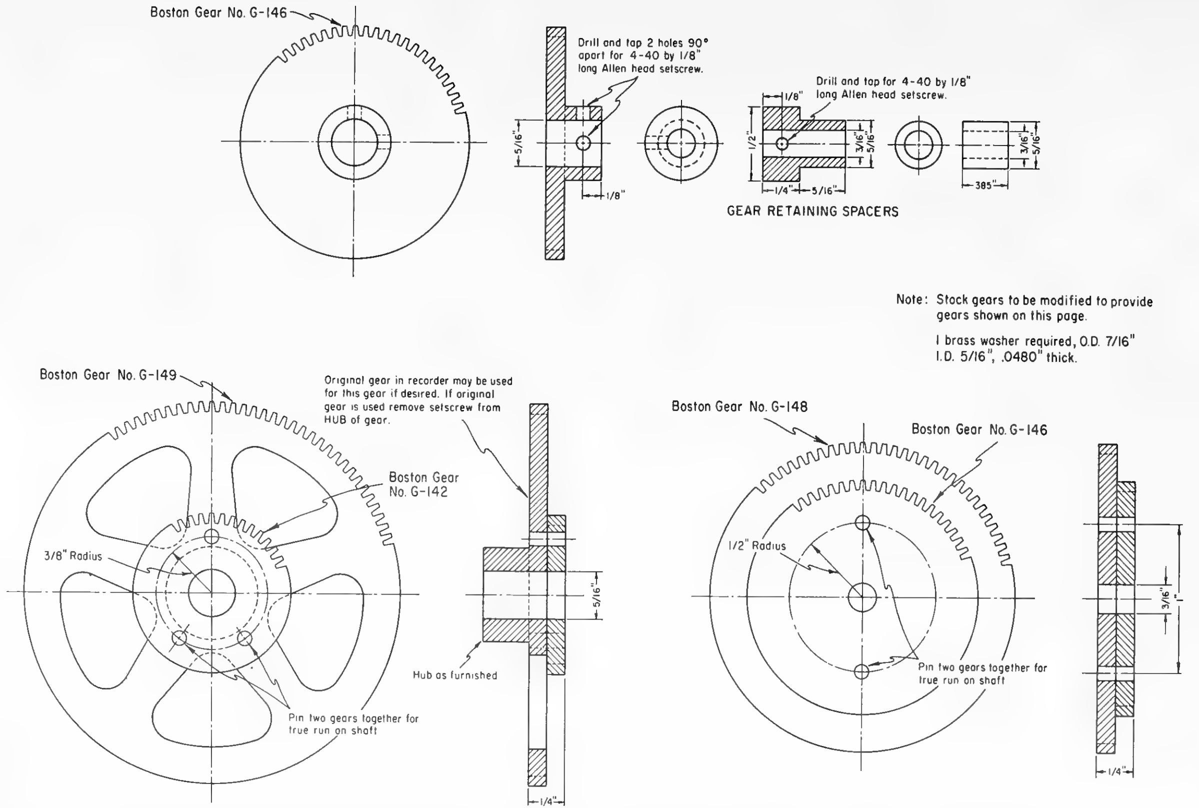


Figure 54. Gear Modification of brush recorder chart drive to furnish chart speeds of 2.5, 12.5,millimeter per second.

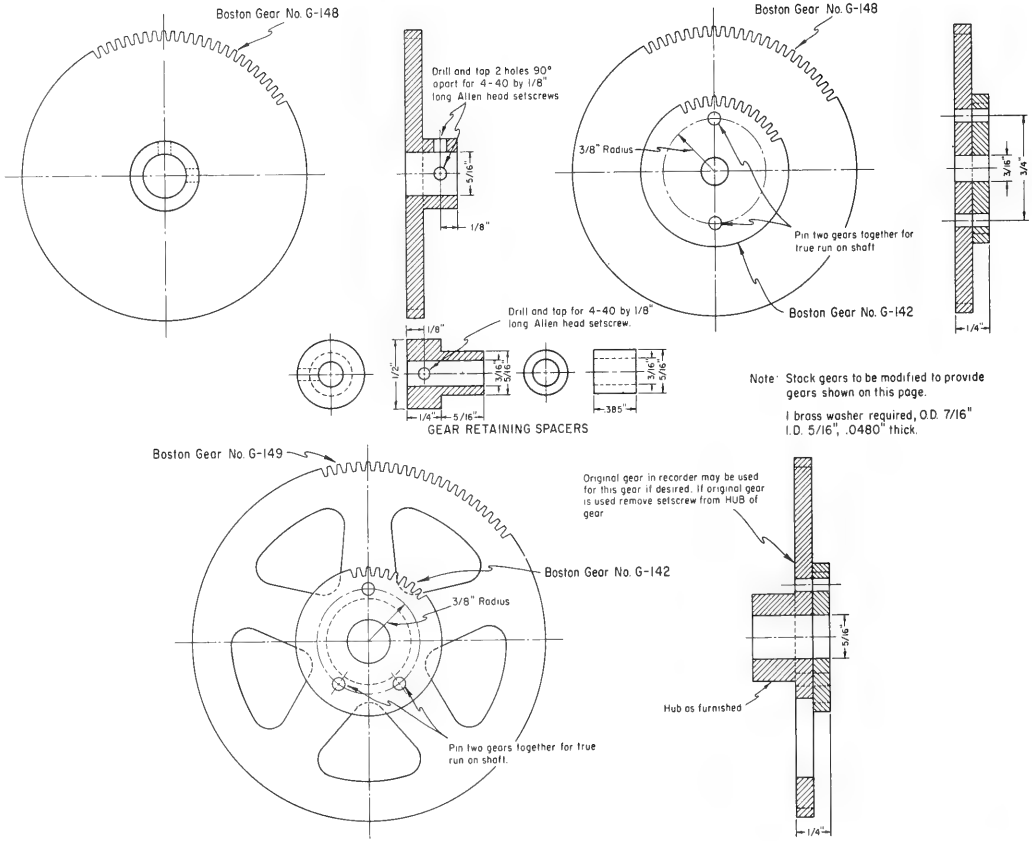


Figure 55. Gear modification of brush recorder chart drive to furnish chart speeds of 1.25, 6.25, or 31.25 millimeters per second.

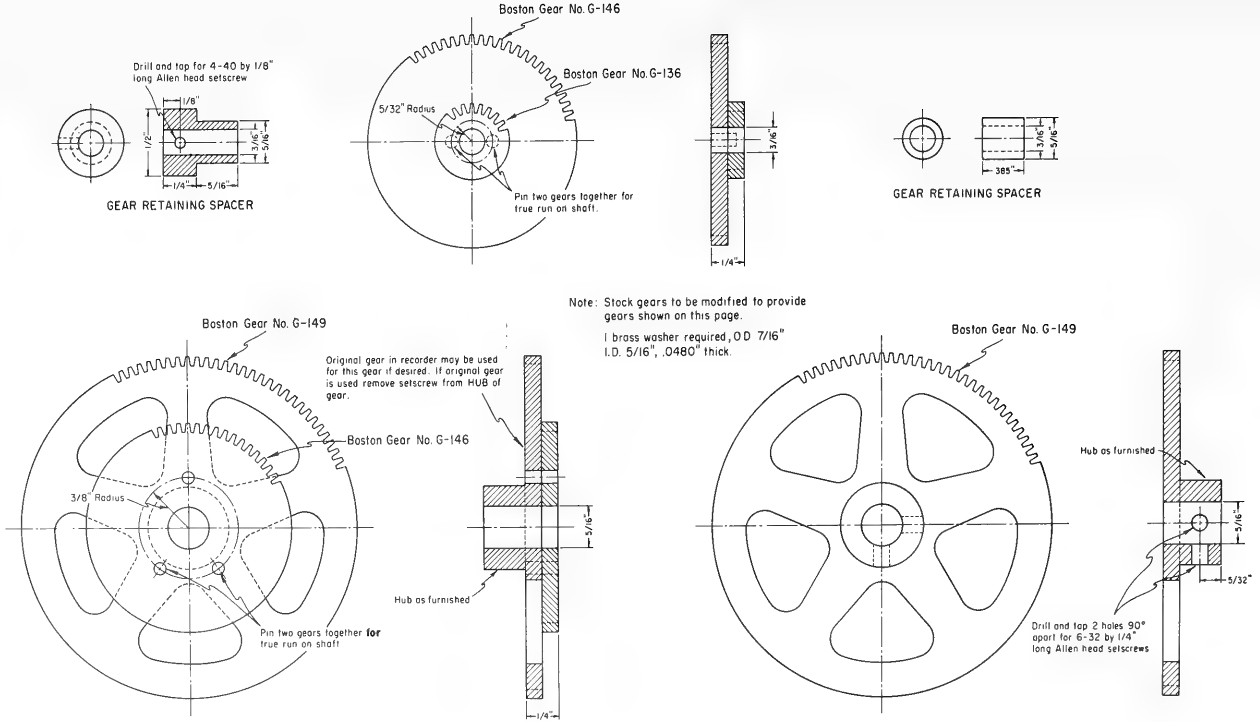


Figure 56. Gear Modification of Brush Recorder Chart Drive to furnish chart speeds of 1.0, 5.0, 25.0 millimeters per second.

h) Remove nuts from secondary gear-cluster shaft.

i) Loosen set screw in collar on left side of recorder main drive shaft.

j) Remove the side frame of the recorder from the recorder base opposite from the motor.

k) Remove large gear from left side of main gear shaft.

l) Remove spacer which holds the smallest gear on main drive shaft.

m) Place new gears and spacers on main drive shaft and on secondary gear-cluster shaft as shown on Figures 57 and 58.

n) Re-assemble recorder, and tighten setscrews in spacers and new drive gear.

o) If gear assembly binds when re-assembled, some hand-fitting of the spacers may be required.

The gear train should run freely when it is properly adjusted.

Lubricate the shafts and gear trains when reassembling. The recorder gear assembly before and after modification is shown on Figures 57 and 58.

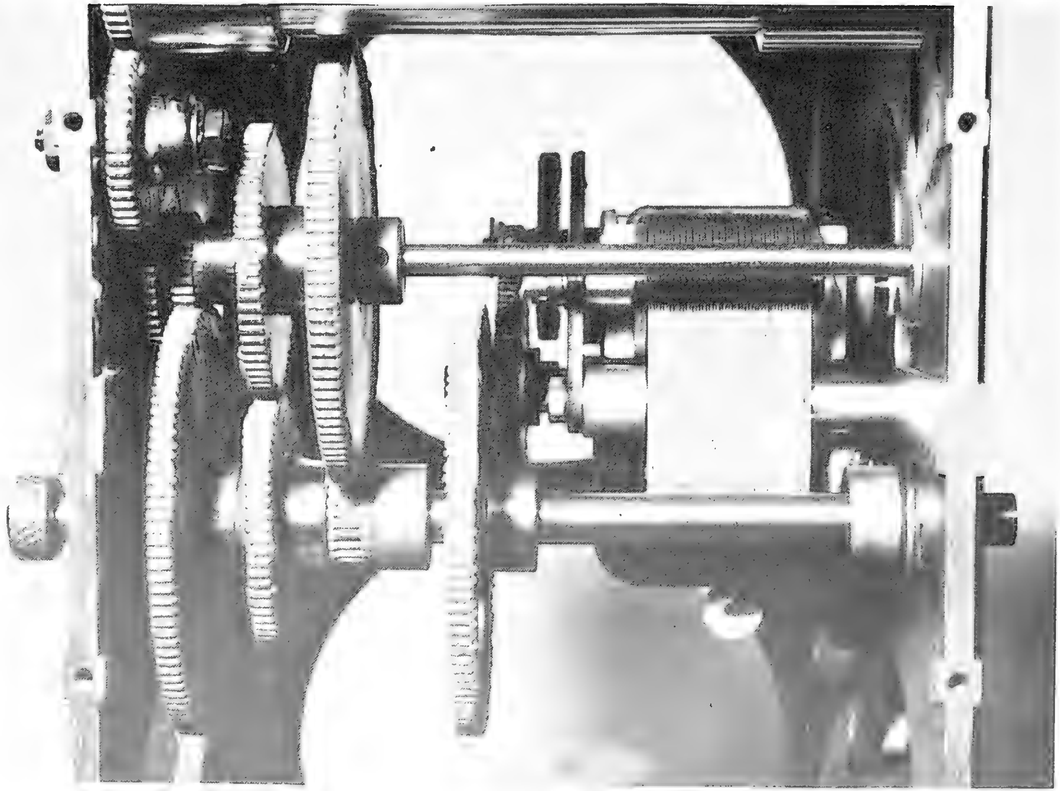


Figure 57. Gear train brush recorder prior to modification.

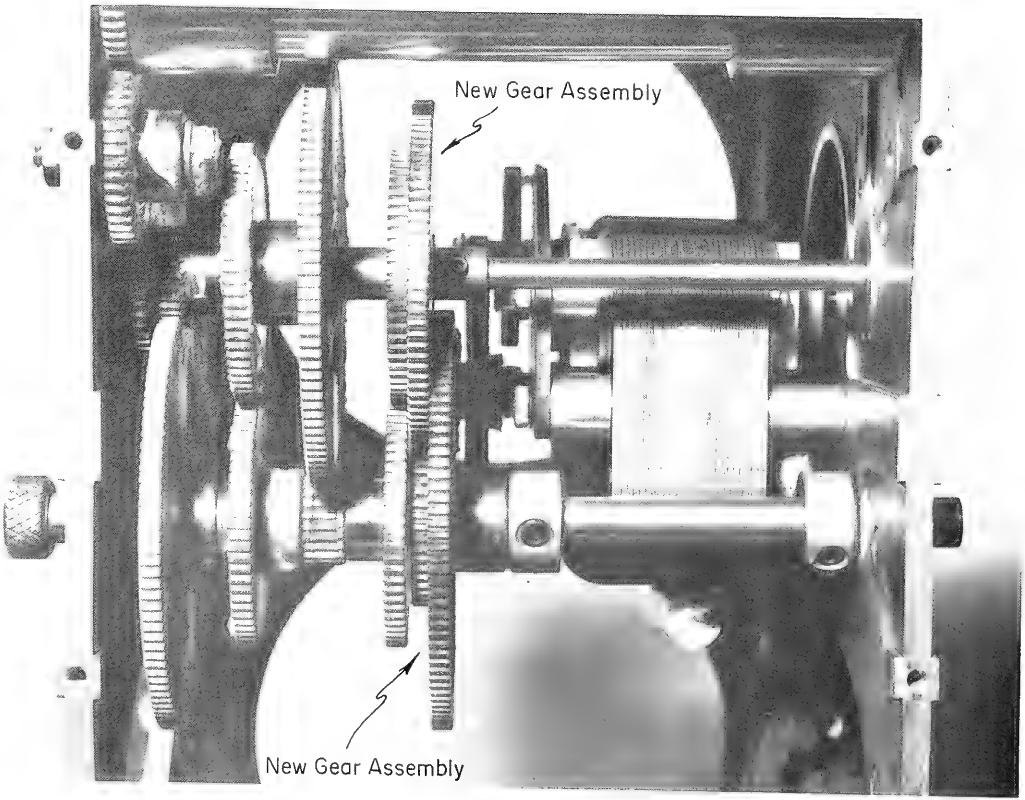


Figure 58. Gear train brush recorder after modification.

Section IX. ANALYSIS OF OCEAN WAVE GAGE RECORDS

1. Step-Resistance Wave Gages

Strip-chart recordings taken at CERC ocean wave recording stations are analyzed for significant wave height, H_s, and significant wave period, T_s.

The visual method used in analyzing strip-chart recordings (as opposed to automatic magnetic tape analysis) for a significant wave height and wave period follows:

a) From a chart run (normally 7 minutes), select as nearly as possible the minute with a wave train which contains most of the highest and most uniform waves.

b) Determine the period of the wave selected in step a) by using the wave-period template according to instructions (Figure 59). When the wave period on the chart falls between two of the periods shown on the template, the analyst may approximate what he considers will be nearest to the exact period. For example, if the period is about halfway between the 5-second template and the 6-second template, then the period is about 5.5 seconds.

c) Use the listing below to determine which wave should be measured to get the approximate significant height of the waves. The wave-height template will aid in determining which wave is to be measured for height.

Wave period (seconds)	Wave to measure
3	3rd highest
3.5	3rd highest
4	2nd highest
5	2nd highest
6	2nd highest
7	2nd highest
8 or longer	1st highest

d) With the proper wave-height template (Figures 60 and 61), determine the height of the wave given by step c) by finding the rectangle on the template whose top line comes nearest to to the crest when the bottom line is on the preceding trough. The wave height, in feet, is indicated by the number on the rectangle.

e) Records with wave heights less than 1/2 foot are listed on the compilation sheet (Figure 62) as calm - without listing the wave height. However, the significant wave period for such records is determined and is indicated on the compilation sheet.

Use: When consecutive crests or troughs of waves as shown on a chart align with consecutive vertical lines on a template, the period of the waves, in seconds, is indicated by the number of the template

For recorder speed of : 6 inches per minute

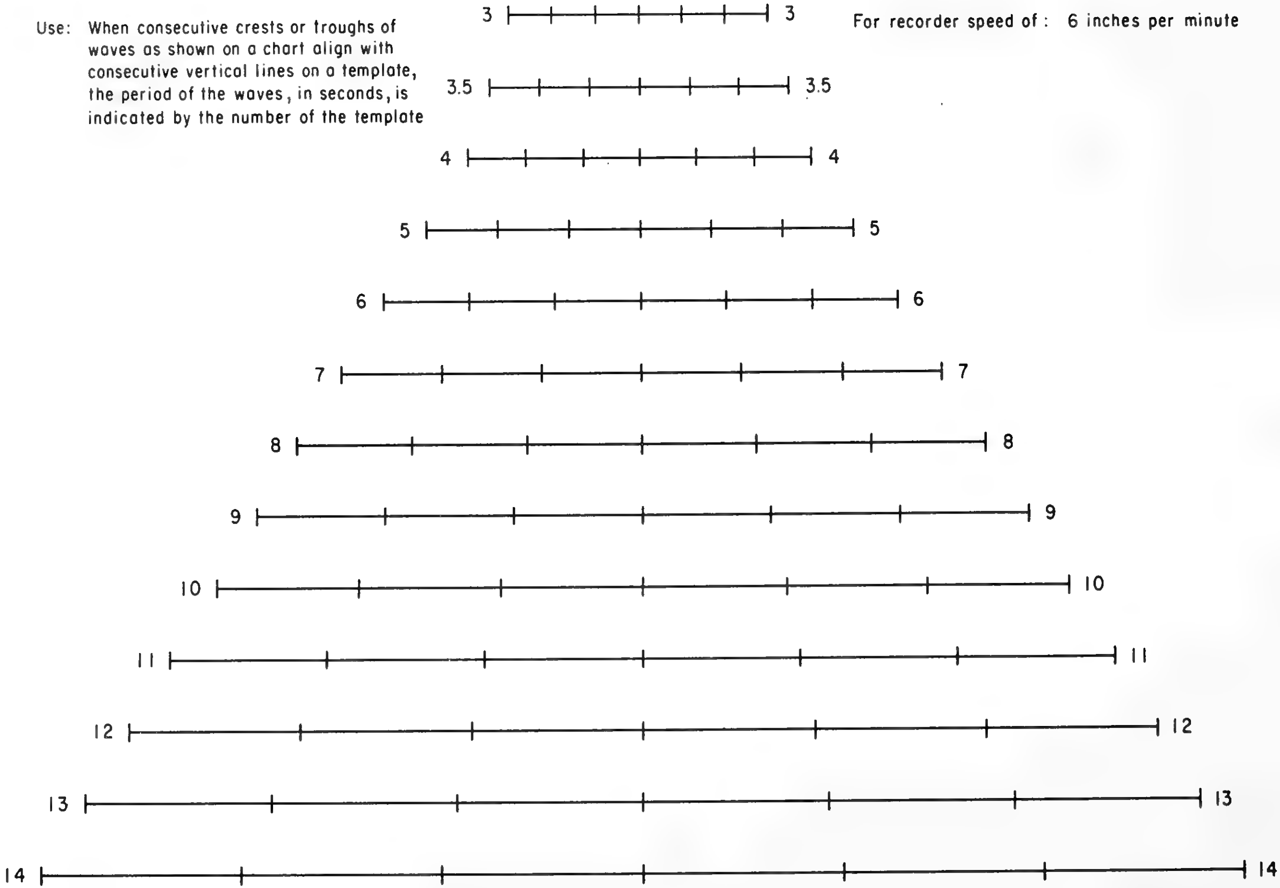


Figure 59. Sample wave-period template (fabricate from clear acetate.)

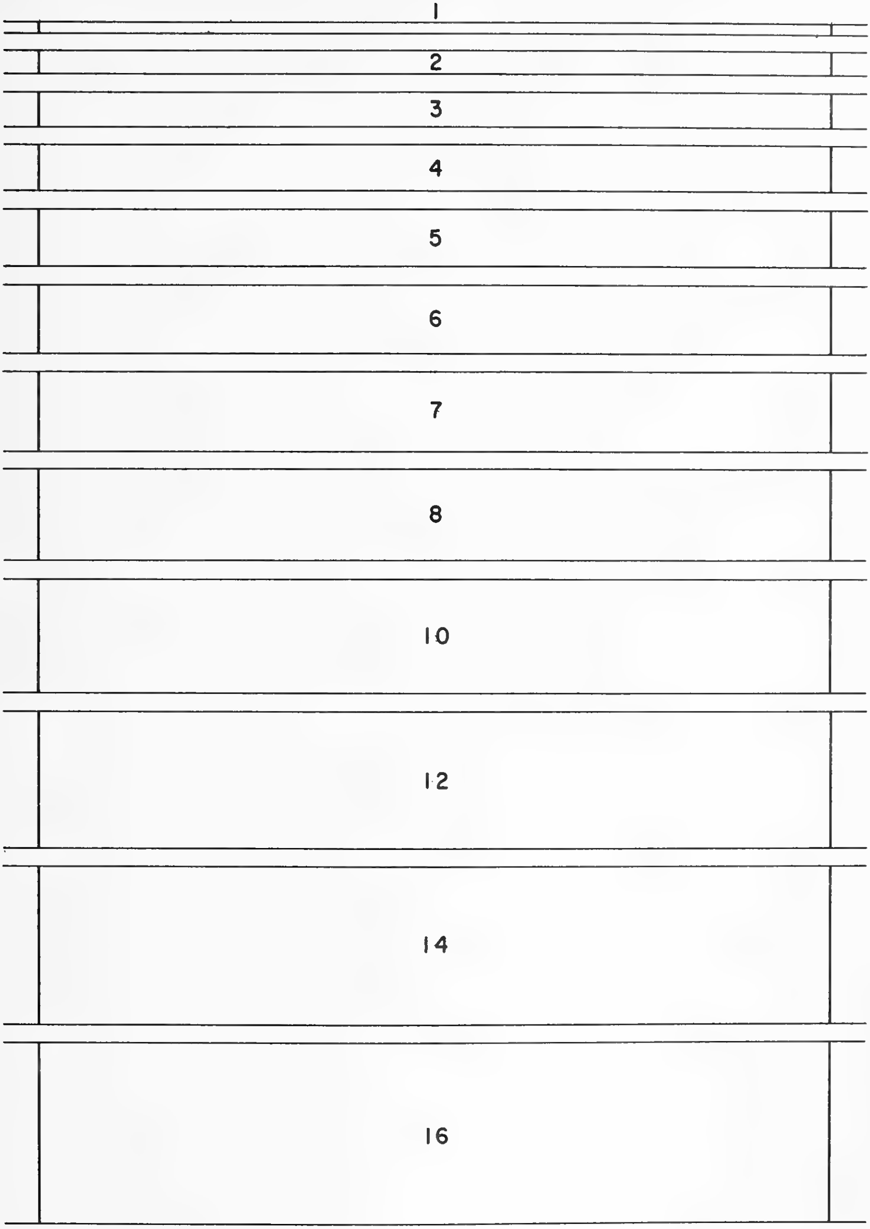


Figure 60. Sample of wave-height template (Fabricate from clear acetate using proper gage calibration.)

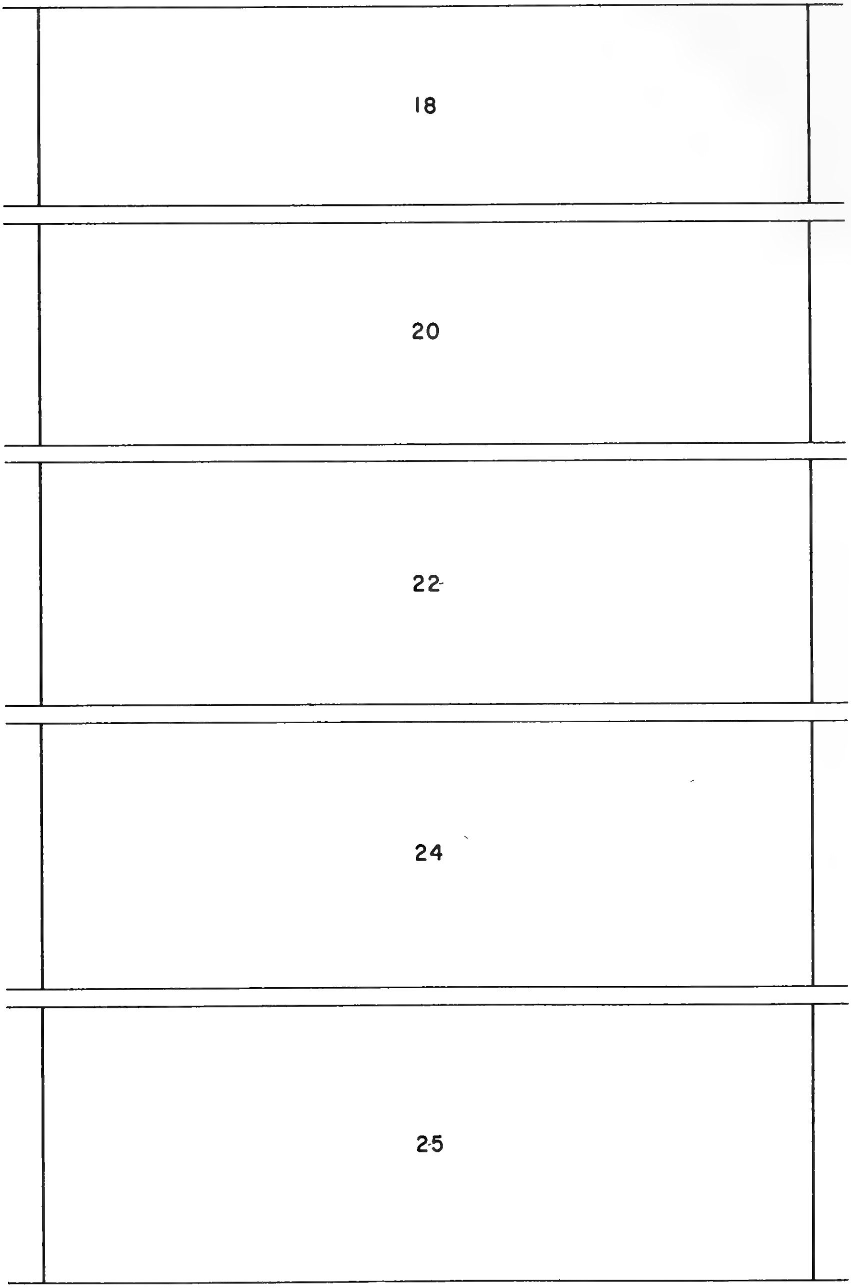


Figure 61. Sample of wave-height template (Fabricate from clear acetate using proper gage calibration.)

Location	Gauge	Recorder
ATLANTIC CITY N J	STAFF	BRUSH

DATE 1965	TIME OF START	PERIOD (SECONDS)	HEIGHT (FEET)		DATE	TIME OF START	PERIOD (SECONDS)	HEIGHT (FEET)
30 Jan	1200	7.0	1.0		8	0000	NO GOOD	
	1600	8.0	1.0			0400	7.0	6.0
	2000	7.0	1.0			0800	10.0	7.0
31	0000	9.0	c +			1200	11.0	9.0
	0400	8.0	1.0			1600	10.0	8.5
	0800	10.0	1.5			2000	10.0	6.5
	1200	9.0	1.5		9	0000	10.0	6.0
	1600	8.0	1.5			0400	8.0	3.8
	2000	8.0	1.5			0800	8.0	3.0
1 Feb.	0000	9.0	1.5			1200	9.0	3.5
	0400	8.0	1.3			1600	8.0	2.5
	0800	NO GOOD	PEN SKIPPED			2000	8.0	2.5
	1200	3.0	1.5		10	0000	8.0	4.0
	1600	5.0	4.0			0400	6.0	4.0
	2000	7.0	7.0			0800	7.0	3.5
2	0000	7.0	4.7			1200	7.0	4.0
	0400	7.0	3.5			1600	7.0	3.0
	0800	10.0	2.2			2000	6.0	3.0
	1200	11.0	1.5		11	0000	6.0	2.5
	1600	9.5	2.0			0400	8.0	2.5
	2000	11.0	2.7			0800	6.0	2.5
3	0000	10.0	2.5			1200	6.0	2.0
	0400	11.0	2.0			1600	6.5	2.0
	0800	11.0	2.0			2000	9.0	2.0
	1200	10.0	2.0		12	0000	6.0	2.0
	1600	9.0	2.0			0400	6.0	2.3
	2000	3.5	1.5			0800	3.5	2.0
4	0000	3.0	1.0			1200	5.0	2.5
	0400	3.0	1.0			1600	5.0	2.5
	0800	7.5	c +			2000	4.5	2.3
	1200	3.0	1.0		13	0000	4.5	2.0
	1600	4.0	1.5			0400	6.0	2.0
	2000	4.0	1.0			0800	7.0	2.5
5	0000	14.0	c +			1200	7.0	1.8
	0400	14.0	c +		#6-65	1600	6.5	1.7
	0800	14.0	c +			2000	6.0	1.0
	1200	14.0	c +		14	0000	7.0	1.2
	1600	3.0	1.5			0400	8.0	1.5
#5-65	2000	5.5	5.0			0800	9.0	1.7
6	0000	7.0	5.0			1200	13.0	2.5
	0400	7.0	3.5			1600	6.0	2.5
	0800	7.0	2.5			2000	6.0	2.0
	1200	6.0	2.0		15	0000	5.0	2.0
	1600	3.0	1.3			0400	5.5	3.0
	2000	4.0	1.5			0800	7.0	3.0
7	0000	3.0	1.3			1200	7.0	3.0
	0400	7.0	1.0			1600	8.0	3.3
	0800	11.0	1.7			2000	10.0	3.7
	1200	3.5	1.7		16	0000	12.0	2.5
	1600	NO GOOD				0400	9.0	2.5
	2000	5.5	5.0			0800	8.0	3.0

BEB-100

Figure 62. Wave-data compilation sheet.

2. Pressure-Sensitive Gages

Due to the depth-period attenuation present when wave recordings are taken using a pressure sensor placed near the ocean bottom, the recordings will require a correction factor to obtain a true wave-height reading.

To obtain the true wave-height data (significant height and significant period), use the following procedure:

a) Determine the significant height and period outlined in the in the method for step-resistance gages.

b) Using the significant period refer to Figure 63 and find the line representing this wave period.

c) Determine the water depth at the time the recording was taken.

d) Intersect the water depth and wave period on the period curve.

e) Read the K (response) factor below the point of intersection.

f) Divide the significant height (found in a) above) by the K factor to obtain a corrected wave height.

The curves apply only to a wave gage mounted on the ocean bottom. If the gage is mounted near the surface, additional curves will be required. Data for preparing these curves (K factor) is available on page D2 and Tables D-1 and D-2 of CERC Technical Report No. 4, "Shore Protection. Planning and Design", 3rd Edition, 1966.

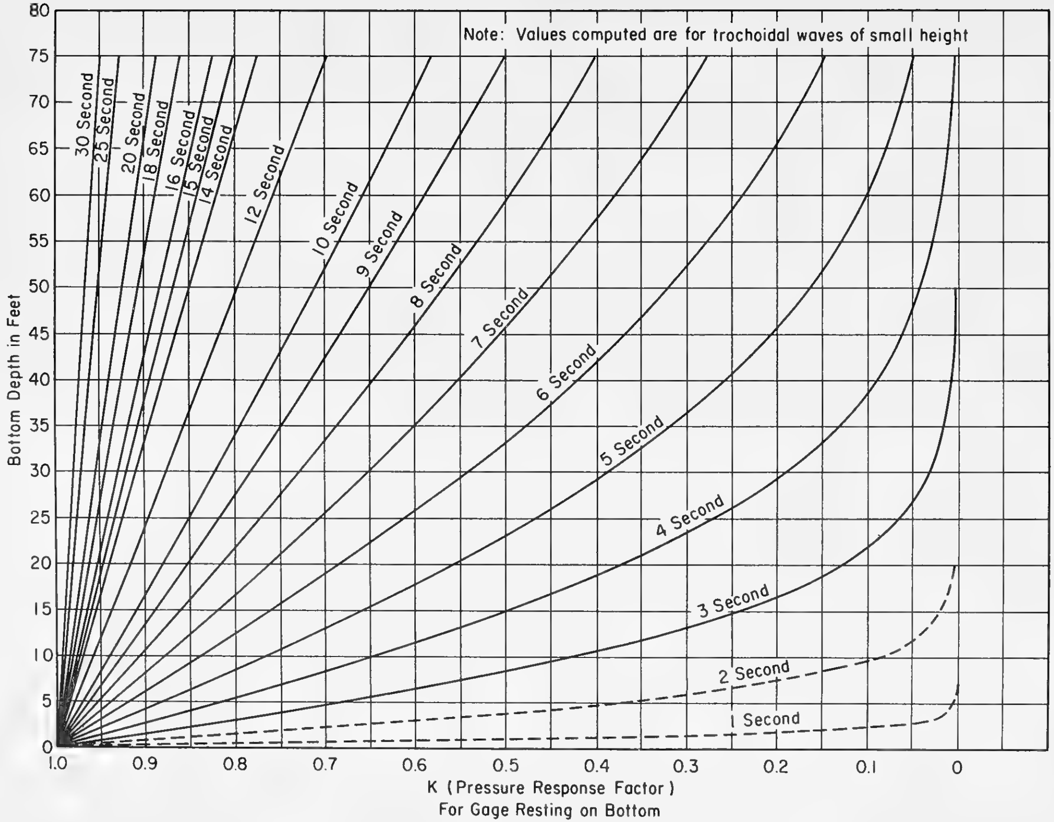


Figure 63. Pressure response curves for various depths and wave periods.

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13. ABSTRACT

CERC has used wave gages to gather prototype wave data since 1948. Two basic types of gages are now used in the field - the step-resistance staff gage and the underwater pressure-sensitive gage. CERC has developed three types of step-resistance staff gages - a series type for use in fresh water, a parallel type for use in salt water, and a relay-operated type for use in either fresh or salt water or in water where wide changes in salinity occur. The pressure gage can be used in water of any salinity. The series and parallel gages have an accuracy of ±5 percent plus the spacing of one sensor increment. The relay gage has an accuracy of ±2 percent plus the spacing of one sensor increment. The accuracy of the pressure-sensitive gage is not as precise as that of the step-resistance gages. The report describes each gage and the theory of operation, details of fabrication, steps for calibration and installation, and requirements of maintenance.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Ocean-wave gages Oceanographic instrumentation Step-resistance wave gages Strip-chart wave records Magnetic tape wave records Wave-record analyzer (magnetic tape)						

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